AD-A146 465 CORRELATION OF FEDERAL TEST METHOD STANDARD 791B METHOD 354 WITH ARMY 240.. (U) SOUTHWEST RESEARCH INST SAN ANTONIO TX ARMY FUELS AND LUBRICA..

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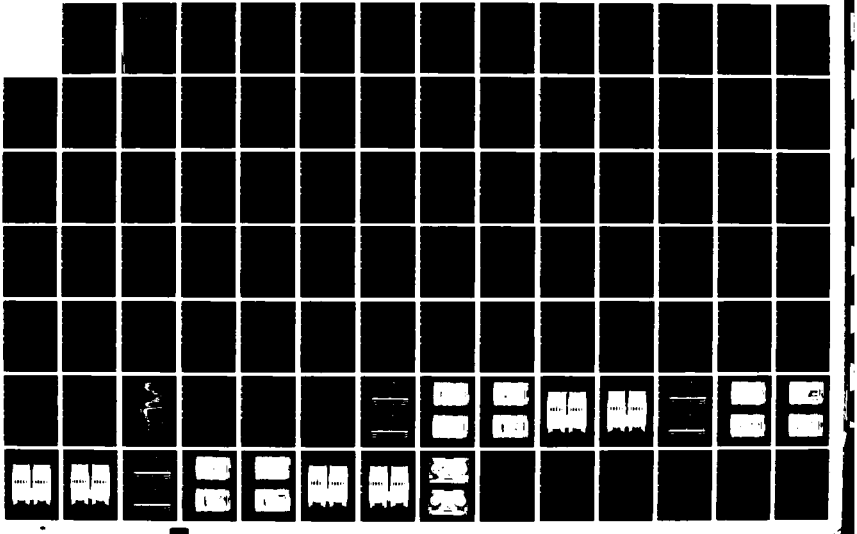

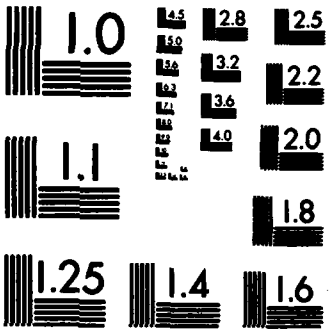

CORRELATION OF FEDERAL TEST METHOD STANDARD 791B METHOD 354 WITH ARMY 240-HOUR TRACKED VEHICLE TEST CYCLE METHOD 355T

FINAL REPORT
AFLRL No. 180

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Under Contract to

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18. SUPPLEMENTARY NOTES

Two unrelated tasks were performed under this contract. This report covers Task II of that effort, while Final Report AFLRL No. 181 covers Task I-Standardization of Flammability Tests for Hydraulic Fluids.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Method 354
Qualification of Engine Oil
Method 355T
Arctic Engine Oil

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Currently the U.S. Army has two full-scale engine tests which are used for qualifying engine oils. Both tests are based on the Detroit Diesel 6V-53T engine with a number of similarities between the two test procedures. The first of these tests is Method 354, FTMS 791B for qualification of MIL-L-46167 arctic engine oils (OEA) while the other is the newly released Method 355T, FTMS 791B for qualification of MIL-L-2104D tactical engine oils (OE/HDO). One of the main differences between these two test

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procedures is that the Method 354 procedure uses an aluminum engine block which is no longer available from the manufacturer. Other differences are that this method is run for a shorter test duration at a lower engine power output level under steady-state conditions. The unavailability of the cast aluminum cylinder block from the manufacturer and the phase-out of this aluminum engine from the Military inventory means that Method 354 must be updated or replaced. This project was an attempt to develop a correlation between the two test methods by comparing results from Method 355T with results from Method 354 using the lubricants used in developing and standardizing Method 354.

FOREWORD

The work reported herein was conducted at the U.S. Army Fuels and Lubricants Research Laboratory located at Southwest Research Institute, San Antonio, Texas, under contract DAAK70-83-C-0070, during the period 5 May 1983 through 30 September 1983. Work was conducted for U.S. Army Belvoir Research and Development Center, Ft. Belvoir, Virginia. Contracting Officer Representative and technical monitor responsibilities were under the Chief, Fuels and Lubricants Division, STRBE-VF, in the Belvoir R&D Center Materials, Fuels and Lubricants Laboratory.

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I. INTRODUCTION

Currently the U.S. Army has two full scale engine tests which are used for qualifying engine oils. Both of these tests are based on the Detroit Diesel 6V-53T engine and there are a number of similarities between the two test procedures. The first of these tests is Method 354, FTMS 791B for qualification of MIL-L-46167 arctic engine oils (OEA) while the other is the newly released Method 355T, FTMS 791B for qualification of MIL-L-2104D tactical engine oils (OE/HDO).(1-4)* One of the main differences between these two test procedures is that the Method 354 procedure uses an aluminum engine block which is no longer available from the manufacturer. Other differences are that this method is run for a shorter test duration at a lower engine power output level under steady-state conditions.

The unavailability of the cast aluminum cylinder block from the manufacturer and the phase-out of this aluminum engine from the Military inventory means that Method 354 must be updated or replaced. The new Method 355T procedure, which is an outgrowth of the original research which produced the Method 354 test, seemed to be an excellent candidate for use in developing a replacement qualification procedure for the MIL-L-46167 lubricants.

This project was an attempt to develop a correlation between the two test methods by comparing results from Method 355T with results from Method 354 using the lubricants used in developing and standardizing Method 354.

II. PROCEDURES AND TECHNIQUES

Engine tests were conducted according to Method 355T, FTMS 791B using lubricants provided by Belvoir R&D Center. A draft copy of Method 355T is included as Appendix A. The tests were run according to the established

*Underlined numbers in parentheses refer to the references at the end of this report.

procedures except that the power levels used during the tests were reduced. Table 1 summarizes the power levels in the various tests. Reduced power levels were required because it was felt that the lower viscosity arctic oils were less capable of protecting the engine than the MIL-L-2104D products for which this procedure was developed. Various levels of derating (indicated by the percentage values in Table 1) were used for different tests as it became obvious that the "marginal pass" lubricant was having difficulty at higher output levels.

III. TEST LUBRICANTS

Three lubricants were used in this test program. The summarized properties of these lubricants are presented in Table 2. The first lubricant was AL-12271-L, OEA lubricant (Lubricant A). This lubricant performed well in Method 354 tests and is a qualified MIL-L-46167 lubricant. A complete list of lubricant properties can be found in Appendix B along with the complete Method 355T test report for this lubricant.

The second lubricant was AL-12272-L, OEA lubricant (Lubricant B). This lubricant was judged to be borderline acceptable in Method 354 tests and is a qualified MIL-L-46167 lubricant. Lubricant properties are listed in Appendices C and D along with complete Method 355T test reports.

The third lubricant was AL-12186-L, a MIL-L-2104B grade OE-10 reference lubricant (Lubricant C). This lubricant failed to meet Method 354 requirements. Again, lubricant properties are listed in Appendix E along with the complete Method 355T test report.

IV. RESULTS

The results of the four tests are summarized in Tables 3 through 6. The first endurance test (No. 31, Appendix B) was run at 8.4 percent derated horsepower conditions using OEA Lubricant A. Analysis of the results indicates that the lubricant performed very well in the test and exhibited low levels of distress.

TABLE 1. SUMMARY OF OPERATING HORSEPOWERS

	2200 RPM	2800 RPM	TESTS
Method 354 (100 Hours)	---	235 (Steady State)	
Method 355T (240 Hours)	265	300	
Method 355T-8.4% (240 Hrs)	243	275	31, 32
Method 355T-21.7% (240 Hrs)	208	235	34, 35

TABLE 2. SUMMARIZED LUBRICANT PROPERTIES

		Test Lubricants		
	Test Method	(OEA) A	(OEA) B	(OE-10) C
K.VIS @ 40C, cst	D 445	27.81	32.00	33.89
K.VIS @ 100C, cst	D 445	6.19	6.37	5.69
VIS INDEX	D 2270	182	155	107
FLASH PT, °C	D 92	244	229	221
SULFATED ASH, % wt	D 874	1.51	1.04	1.06
ELEMENTS % wt				
Ba	XRF*	0.88	<0.01	0.50
Ca	XRF	<0.01	0.28	<0.01
Zn	XRF	<0.01	0.10	0.08
P	XRF	<0.01	0.09	0.11
BOILING POINT DISTRIBUTION				
°C @ 10% wt	GC**	439	406	379
°C @ 30% wt	GC	448	425	408
°C @ 50% wt	GC	452	437	429
°C @ 70% wt	GC	459	452	451
RESIDUE, wt %				
>600C	GC	0	8	5
EVAP. LOSS, 191C, WT %	D 972	9	20	30

*XRF = X-Ray Fluorescence Method
**GC = Gas Chromatographic Method

TABLE 3. SUMMARY SHEET FOR TEST NO. 31

Lubricant A, OEA

Test Hours Completed: 240 derated 8.4%
Replaced Liner: None
Worst cylinder: 2R

	Avg of Best 5	Worst Cylinder	Avg of all 6
Piston WTD	277	279	277
Hot Stuck Rings	0	0	0
Fire Ring Face Demerits	8.2	12.0	8.8
2&3 Ring Face Demerits	0.75	15.0	3.1
Liner Scuffing,%	3.3	4.5	3.5
Liner Scuffing,% by mat	NR	NR	NR
Port Plugging,%	<1	<1	<1
Valve Burning	0	0	0
Fire Ring End Gap Change, in	0.002	0.008	0.003
Oil Consumption, lbs/hr	0.39		
Fe,ppm,@EOT	20		

Comments:
1. EOT=End Of Test.
2. NR=Not Rated.

TABLE 4. SUMMARY SHEET FOR TEST NO. 32

Lubricant B, OEA

Test Hours Completed: 60 derated 8.4%
Replaced Liner: None
Worst cylinder: 3R

	Avg of Best 5	Worst Cylinder	Avg of all 6
Piston WTD	197	232	202
Hot Stuck Rings	0	0	0
Fire Ring Face Demerits	22.0	72.5	30.4
2&3 Ring Face Demerits	22.2	35.6	24.4
Liner Scuffing,%	17.4	100.0	31.2
Liner Scuff,% by mat	17.2	100.0	31.0
Port Plugging,%	<1	<1	<1
Valve Burning	0	0	0
Fire Ring End Gap Change, in	0.002	0.008	0.003
Oil Consumption, lbs/hr	0.44		
Fe,ppm,@EOT	205		

Comments:
1. 2L and 3R fire rings collapsed.
2. #2 and #4 main bearings worn severely and spalled.
3. EOT=End Of Test.

TABLE 5. SUMMARY SHEET FOR TEST NO. 34

Lubricant B, OEA

Test Hours Completed: 240 derated 21.7%
Replaced Liner: None
Worst cylinder: 3R

	Avg of Best 5	Worst Cylinder	Avg of all 6
Piston WTD	226	266	233
Hot Stuck Rings	0	0	0
Fire Ring Face Demerits	17.3	61.3	24.5
2&3 Ring Face Demerits	15.5	58.1	22.6
Liner Scuffing,%	22.5	91.0	33.9
Liner Scuff,% by mat	29.1	96.0	40.3
Port Plugging,%	<1	<1	<1
Valve Burning	0	0	0
Fire Ring End Gap Change, in	0.0	0.007	0.002
Oil Consumption, lbs/hr	0.54		
Fe,ppm,@EOT	110		

Comments:
1. Small oil leak during test, impossible to quantify.
2. EOT=End Of Test.

TABLE 6. SUMMARY SHEET FOR TEST NO. 35

Lubricant C, OE-10

Test Hours Completed: 20 derated 21.7%
Replaced Liner: None
Worst cylinder: 1L

	Avg of Best 5	Worst Cylinder	Avg of all 6
Piston WTD	147	152	147
Hot Stuck Rings	0	0	0
Fire Ring Face Demerits	30.0	60.0	35.0
2&3 Ring Face Demerits	26.1	56.9	31.2
Liner Scuffing,%	42.5	93.0	50.9
Liner Scuff,% by mat	47.6	94.5	55.4
Port Plugging,%	<1	<1	<1
Valve Burning	0	0	0
Fire Ring End Gap Change, in	0.012	0.009	0.011
Oil Consumption, lbs/hr	0.54		
Fe,ppm,@EOT	320		

Comments:
1. No.1 ring on 2R collapsed.
2. EOT=End Of Test.

The second test (No. 32, Appendix C) was run under the same derated horsepower conditions using OEA Lubricant B. The test completed only 60 hours before severe liner scuffing and bearing distress forced test shutdown to avoid catastrophic failure. Two liners were severely scuffed, and bearing distress was evident throughout the engine. This was judged to be a lubricant-related failure.

The third test (No. 34, Appendix D) again utilized OEA Lubricant B as the test lubricant. This time, however, the horesepower was derated 21.7 percent in order to further lessen the severity of the test. The test ran to completion but exhibited levels of distress which are considered borderline acceptable (by definition) based on field performance.

The fourth test (No. 34, Appendix E) utilized MIL-L-2104B OE-10 reference oil, Lubricant C, and was run at 21.7 percent derated horsepower conditions. The test ran only 20 hours before severe liner scuffing in three cylinders forced test shutdown in order to avoid catastrophic failure. High engine oil iron content was also noted at 20 test hours.

Selected results of these four tests are compared to Method 354 results in Table 7.(5)

V. CONCLUSIONS

These four tests indicate that FTMS 791B Method 355T may adequately distinguish the lubricant quality of MIL-L-46167 OEA lubricants when run at 21.7 percent derated horsepower conditions. The derated Method 355T tests ranked the oils in the same order as past Method 354 tests and field experience. (5-7) Lubricant A performed well at 8.4 percent derated conditions and should continue to do so at 21.7 percent derated conditions. Lubricant B completed the test and exhibited borderline acceptable characteristics (based on scuffing and ring face distress) when run at the 21.7 percent derated conditions. This lubricant was judged a borderline pass in the Method 354 tests. Lubricant C exhibited definite "failure" characteristics (based on failure to complete the test and high distress levels) in both the Method 354 and 355T tests.

TABLE 7. COMPARISON OF METHOD 354 TESTS TO METHOD 355T TESTS

	OEA LUBRICANT A		OEA LUBRICANT B		OE-10 LUBRICANT C	
Test Method	354	355T	354	355T	354	355T
Test Number	9A	31	8	34	7	35
Hours Completed	100	240	98	240	4*	20
Power Reduction, %	0	8.4	0	21.7	0	21.7
Hot Stuck Rings	0	0	0	0	1	0
Ring Face Demerits Or Burning **	3H3L	3.1	4H2L	22.6	1H5L	31.2
Liner Scuffing, %	27	3.5	46	33.9	20	50.9
Fire Ring End Gap Change, in x .001	NR	3	NR	2	NR	11
Oil Consumption,lbs/hr	0.46	0.39	0.41	0.54	3.6	0.54
Fe, ppm, @ EOT	NR	20	NR	110	NR	320
Qualitative Judgement	ACC	ACC	BLA	BLA	FAIL	FAIL

Notes:
1. EOT=End Of Test.
2. NR=Not Rated.
3. * This test exhibits low liner scuffing and ring burning due to the low number of hours run prior to catastrophic siezure in 3L.
4. ** For Method 355T tests this is the average of 2&3 ring face demerits. For Method 354 tests H=Heavy, M=Medium and L=light ring face distress, preceded by the number of cylinders exhibiting that level of distress on all compression rings.
5. ACC=Acceptable, BLA=Borderline Acceptable.

VI. RECOMMENDATIONS

- Other derated Method 355T tests should be performed using MIL-L-46167 lubricants of proven quality in order to verify the above conclusions and so evaluate repeatability.
- If the derated test continues to successfully discriminate MIL-L-46167 lubricant quality, then pass/fail limits should be established and it should replace Method 354.

VII. REFERENCES

1. U.S. Military Specification MIL-L-2104D, Lubricating Oil, Internal Combustion Engine, Tactical Service, April 1983.
2. U.S. Military Specification MIL-L-46167, Lubricating Oil, Internal Combustion Engine, Arctic, February 1974; Amendment 1, May 1978.
3. Method 354, Federal Test Method Std. 791B, "Performance of Arctic Lubricating Oils in A Two-Cycle Engine Under Steady State Turbosupercharged Conditions," June 1974.
4. Method 355T, Federal Test Method Std. 791B, "6V-53T 240-Hour Tracked Vehicle Cycle Endurance Test Procedure--Performance of Engine Lubricating Oils in A Two-Cycle Diesel Engine Under Cyclic, Turbo-Supercharged Conditions," July 1982.
5. S. J. Lestz, "Development of a Diesel Engine Test Technique for Evaluating Arctic Engine Oils," Final Report AFLRL No. 24, AD 768901. Conducted under Contract DAAD05-70-C-0250, September 1973.
6. S. J. Lestz and T. C. Bowen, "Development of Army Synthetic Automotive Engine Oils for Arctic Service," AFLRL Interim Report No. 73, AD A019113, September 1975.
7. S. J. Lestz and T. C. Bowen, "Army Experience with Synthetic Engine Oils in Mixed Fleet Arctic Service," SAE Paper No. 750685, presented at National F&L Meeting, Houston, Texas, June 3-5, 1975.

APPENDIX A

6V-53T 240-HOUR TRACKED-VEHICLE CYCLE ENDURANCE TEST PROCEDURE

DRAFT

Date 7-15-82

6V-53T 240-HOUR TRACKED VEHICLE CYCLE ENDURANCE TEST PROCEDURE

PERFORMANCE OF ENGINE LUBRICATING OILS IN A TWO-CYCLE DIESEL ENGINE UNDER CYCLIC, TURBO-SUPERCHARGED CONDITIONS

1. SCOPE

1.1 This method is used for determining the effect of lubricating oils on wear, ring-sticking, and accumulation of deposits in a reciprocating internal combustion engine. Evaluation is based on: (a) the ability of the test engine to maintain performance throughout the cycle, (b) wear of critical engine components, (c) accumulation of fuel and lubricant related engine deposits, particularly in the piston ring zone areas, and (d) the physical and chemical condition of the lubricant monitored throughout the test.

1.2 The test involves the operation of a militarized six-cylinder, fuel injected, turbo-supercharged, 2-stroke-cycle diesel engine under cyclic conditions for a total of 240 hours. Prior to test the engine is reconditioned as described herein. Evaluation is made by comparing the test oil performance to that of a reference oil of known quality.

2. SAMPLE

2.1 A minimum of 55 gallons of test oil is required.

3. APPARATUS

3.1 References.

3.1.1 Coordinating Research Council Diesel Engine Rating Manual No. 5.

3.1.2 Proposed CRC Rating System for Diesel Engine Deposits, CRC, Inc., New York, NY, February 1973. This is a good reference but not mandatory.

3.1.3 Detroit Diesel Engine Series 53 Service Manual.

3.1.4 Method 346.2 Federal Test Method Standard 791.

3.2 Test Engine Systems.

3.2.1 Test Engine. A Detroit Diesel 6V-53T Engine (Military Model 5063-5395), is specified for this method, with the following parts:

Quantity	Detroit Diesel Part No.	Item
1	5133512	Flywheel
1	5126671	Scuff Plate
6	9409129	Bolt
1	5101431	Turbocharger
1	5133427	Heat Exchanger
1	8539953	Transmission Cooler (8 pl.)
1	8528885	Oil Cooler (16 pl.)
6	5140949	Connecting Rod
6	5228784	Fuel Injector (M70 or N70)
1	5199793	Overhaul Gasket Kit
8	AC-A86CW	Air Filter
4	5132924	Hand Hole Gasket
1	AC-T552	Primary Fuel Filter
1	AC-TP540	Secondary Fuel Filter
2	AC-PF132W	Oil Filter
24	5197176	Exhaust Valves
6	5149315	Liner, Piston, Ring Set
6	5109970	Upper Oil Control Ring & Expander

3.2.2 Air Intake System. A special air intake system is required for this method. The low temperature air-heater and primer assembly shall be removed from the engine. The air barrel assembly, described in Appendix A, is attached in the horizontal position to the turbocharger compressor.

3.2.3 Crankcase Ventilation System. The crankcase breather system described herein shall be used for this method. The breather pipes are joined at a tee connection and connected to a short piece of 1-1/4 inch rubber hose. The total gas flow is then piped by 1 inch conduit to the blowby surge chamber from which the gas passes through a blowby meter and is discharged vertically. Appendix B illustrates the blowby surge tank. The airbox is drained from the left and right airbox drains through #49 orifices and into one gallon collection cans. Filters may be placed before the orifices in order to prevent orifice plugging.

3.2.4 Cooling System. The coolant flow shall be from the thermostat housing cover outlet, through a 2 inch diameter transparent section of pipe into the coolant heat exchanger and back to the suction side of the coolant pump. A one-gallon cylindrical surge tank (6-1/2 inches diameter by 8-1/2 inches long) located to the side and above the coolant heat exchanger is provided as a settling vessel to insure coolant deaeration. During test the cooling system is operated with the pressure cap in the vented to atmospheric position. The engine thermostats are blocked in the full-open position for this test. Coolant heat exchanger shall be a BCF American Standard 5-030-06-024-006 or equal. System coolant capacity is six gallons. Coolant flow rate may be measured and reported.

3.2.5 Fuel System. The primary and secondary fuel filter assemblies are relocated to a remote position off the engine and away from the heat of the exhaust gas. The same premium grade fuel lines (minimum length) and fittings supplied with the engine must be used when relocating the fuel filters. A water-to-fuel heat exchanger is employed to maintain fuel temperature. All lines must be lagged and secured to protect against vibration damage. Appendix C illustrates the fuel system.

3.2.6 Oil System. The 1/4 inch pipe plug in the front of the oil filter housing shall be removed and a sampling valve installed in its place. The oil filter housing is moved to an off engine location. Appendix D illustrates the oil system. No additional oil cooling is allowed.

3.3 Instrumentation.

3.3.1 Load Measurement. Appropriate engine speed and load-indicating devices, from which observed BHp can be determined, must be used in conjunction with suitable power-absorbing equipment. Engine or dynamometer speed shall be measured with an automatic electric revolution counter with synchronized time or suitable electronic speed measuring device. Accuracy of the load measuring device shall be ±3 ft-lb.

3.3.2 Flow Measurement.

3.3.2.1 Fuel Flow. Provision shall be made for mass flow fuel measurement with a resolution of ±0.10 pounds per hour. Average fuel temperature is determined at the fuel measuring device and fuel density is established. The fuel-flow measuring device shall be a properly installed mass flow meter.

3.3.2.2 Blowby Flow. Blowby flow is indicated with the equipment described in 3.2.3 and Appendix B.

3.3.3 Temperature Measurements. Provisions shall be made for thermocouple installations as shown below (total system accuracy shall be calibrated to ±2°F). Thermocouples shall be shielded, and, unless specified, shall be immersed to the midstream.

Variable	Location
Exhaust gas before turbocharger	Left and right elbows, 2-3/4 inches from manifold
Turbocharger exhaust exit	2-1/4 inches from turbocharger exit
Cylinder jacket coolant-in*	1.5 inch above the inlet end of water pump inlet
Cylinder jacket coolant out*	In 1/2 inch pipe plug hole of thermostat housing deaeration dome
Oil sump*	Sump drain plug, 2-5/8 inches immersion from wall
Fuel*	At secondary filter inlet
Compressor inlet air*	Inlet air barrel, opposite No. 1 air filter (see Appendix A)
Airbox*	Left rear hand hole cover
Wet bulb/dry bulb	Near air barrel inlet

* All temperatures shall be recorded at not more than 2 minute intervals during the test.

3.3.4 Pressure Measurements. Provision shall be made for measuring pressures as follows:

Variable	Location
Intake air vacuum	After air filters, 4 inches from compressor inlet
Exhaust back pressure	In 4 inch line, 3 inches after turbocharger exit
Exhaust pressure before turbocharger	Right-hand elbow, 3 inches from turbocharger Y connector
Compressor discharge	Blower inlet housing (remove 1/4 inch pipe plug)
Airbox	Left rear hand hole cover
Oil gallery	Left rear gallery top
Fuel	Secondary filter outlet
Barometer	In vicinity
Blowby	In blowby surge tank

4. MATERIALS

4.1 Fuel. Only fuels approved by the U.S. Army Mobility Equipment Research and Development Command, Energy and Water Resources Laboratory, Ft. Belvoir, Virginia, and meeting the requirements set forth in section 4.1.1, Federal Test Method 346.2, Federal Test Method Standard 791 shall be used for this method.

4.2 Reference Oil. Reference engine oil REO-203 is to be used for standardizing engine operation as set forth herein. Orders for reference oil should be made out to Southwest Research Institute, P.O. Drawer 28510, San Antonio, Texas 78284 and sent to the ASTM Test Monitoring Center, 4400 5th Ave, Pittsburgh, PA, 15213, Attn: Mr. P.R. Eisaman for transmittal to the supplier.

4.3 Cleaning Compound Special. Gulf H-236 "Stoddard" solvent or Exxon "Varsol" may be used to clean parts as described herein. D-Carb (Dubois Chemicals Co., Cincinnati, Ohio) may be used in vat cleaning the engine block.

4.4 Engine Coolant. Engine coolant will consist of a 50/50 volumetric mixture of ethylene glycol base antifreeze* and potable water.

*Prestone--mixing with other types not authorized.

5. PREPARATION FOR TEST.

5.1 Engine Disassembly. A systematic inspection and maintenance of the test engine shall be performed prior to each test run. New engines or engines being used for the first time in this test method and thereafter will be disassembled, reconditioned, and gauged before each test. Regardless of their condition, the following parts shall be replaced with new factory production items:

Piston Assemblies
Piston Ring Sets
Cylinder Liners
Fuel Filters, Oil Filter, and Air Filters
All Gaskets and Seals

The measurements prescribed in Appendix E (BEFORE AND AFTER TEST DATA SHEETS) shall be performed and recorded.

5.2 Cleaning Procedure.

5.2.1 Engine Block. If the engine is completely disassembled, the block shall be cleaned by spraying with solvent.

5.2.2 Aluminum Parts. Aluminum parts will be cleaned by spraying with solvent followed by air drying. If deposits are stubborn, the parts may be soaked in solvent for a period up to two hours at a temperature of 100°F or less. The solvent soak must be followed by a warm water wash and air drying.

5.2.3 Steel Parts. All steel parts (i.e., rocker arm covers, oil pan, oil heat exchanger, cylinder head decks, oil pump, crankshaft, etc.), shall be cleaned by spraying with solvent, air dried and lightly coated with reference oil.

5.2.4 Fuel Injectors. The fuel injectors are removed but not disassembled or adjusted. Only the tips should be lightly wire brushed to remove carbon particles. Should the operation of the engine indicate that their condition might be at fault, the units should be tested, adjusted, and/or replaced with new units.

5.2.5 Combustion Chambers and Valves. Exhaust valves are removed and the entire combustion chamber area of each cylinder is cleaned by wire brushing. Valves are only lightly refaced, if inspection shows pitting. Where the sealing surfaces (faces) are not pitted, the valves need be only lightly lapped prior to reassembly. If light refacing does not correct the seating condition, the valve shall be replaced. Regardless of their condition, valves should be replaced after three tests.

5.3 Engine Disassembly. The engine block is fitted with new parts as listed in sections 3.2.1 and 5.1. Complete measurements of the block bore, liners, pistons, rings, connecting rod journals, main bearing journals, connecting rod bearing inserts, and main bearing inserts are made prior to each rebuild. Connecting rods and piston pins will be inspected and replaced if not in good service conditon. In addition, camshaft journals to bearings and oil pump clearances shall be checked against service limits during major

rebuilds. These parts will be replaced as required to maintain service limits. The liner outside surfaces contacting the block bore shall be lightly coated with grease to reduce interface fretting corrosion. Other parts shall be coated with reference oil during assembly. Piston pin retainers shall be checked for leakage with KENT MOORE tool number J-23987-01.

5.3.1 The following critical rebuild measurements shall be maintained during engine assembly:

Engine Part	Tolerance or Clearance[1] - Inches
Crankshaft main bearing clearance	0.0010-0.0040
Camshaft bearing clearance	0.0045-0.0060
Connecting rod bearing clearance	0.0011-0.0041
Crankshaft end-play	0.0040-0.0110
Cylinder block bore	
Taper	0.0015 max
Out-of-round	0.0015 max
Inside diameter	4.3565-4.3575 new
Clearance liner to block	0.0005-0.0025
Cylinder liners (installed)	
Taper	0.0015 max[2]
Out-of-round	0.0015 max[2]
Inside diameter	3.8752-3.8767
Piston to liner fit	0.0061-0.0098
Piston skirt O.D.	3.8669-3.8691
#1 Fire Ring	
End gap	0.020-0.046
Side clearance	0.003-0.006
#2 Compression ring	
End gap	0.020-0.036
Side clearance	0.007-0.010
#3 Compression ring	
End gap	0.020-0.036
Side clearance	0.005-0.008
#4 Compression ring	
End gap	0.020-0.036
Side clearance	0.005-0.008
#5, 6, 7, Oil rings	
End gap	0.010-0.025
Side clearance	0.0015-0.0055

(1) All tolerances and clearances given in inches.
(2) Using new cylinder liners in a used block.

5.3.2 Engine assembly shall be in accordance with TM 9-2815-212-35 and the Detroit Diesel Engine Series 53 Service Manual. Reference must be made to these documents to determine the proper bolt torques, tightening sequences, and final injector timing and valve lash settings. Upper oil control ring expander accompanying DD part number 5109970 shall be installed in place of expanders accompanying liner-piston-ring set.

6. ENGINE CONDITIONING AND CALIBRATION PROCEDURES

6.1 Engine start-up and shut-down procedures.

6.1.1 Engine Start-up Procedure. From a cold start, idle the engine for five minutes. Then warm up at 1200 rpm and 88 lb-ft dynamomter load (20 BHp) until oil sump temperature reaches 180°F and coolant jacket-out temperatures reach 170°F. If the coolant system was drained at the previous shut-down, warm up at 1100 rpm and 72 lb-ft load (15 BHp) to insure deaeration of the coolant system. If the engine is started warm and the 180°F oil sump and 170°F coolant jacket-out temperatures are achieved, it is permissible to gradually accelerate the engine without delay to test conditions. The automatic controller set point for coolant-out temperature must remain at 170°F during all startups except when the test is being resumed at the idle modes described in 7.5.

6.1.2 Engine Shut-Down Procedure. To shut down the engine from test conditions, slowly bring the engine to idle by turning the rack setting to the idle position. Allow the engine to idle for five minutes and then shut-down by actuating the idle cut-off. The automatic controller set point for coolant out temperatures must remain at 170°F during all shut-downs.

6.2 Engine Run-In Procedure.

6.2.1 Oil Charge. Charge the engine oil sump with approximately 24 quarts of reference oil. Disconnect the turbo oil supply line at the turbo and crank the engine with the governor control in the fuel cut-off position until one pint of oil is pumped from the disconnected line. Reconnect the turbo line and crank the engine until the oil pressure stabilizes.

6.2.2 Operating Conditions. Start the engine in accordance with 6.1.1 and conduct the engine run-in according to the following schedule:

Engine Speed, rpm	Dynamometer Load, lb-ft	Power, Obs BHp	Time, min.
1800	88	30	15
2200	310	130	30
2500	420	200	30
2800	422	225	30

Coolant jacket-out temperature is maintained at 170 ± 2°F, and oil gallery pressure is 30 psi minimum. Coolant system deaeration (air free sight glass) must be established by the time the 2500 rpm sequence is completed.

6.3 Interim Settings and Adjustments.

6.3.1 Immediately following the run-in, check, adjust and record the governor settings. Set the idle speed at 650-700 rpm maintaining a minimum of 5 psi gallery oil pressure. No-load speed maximum should be 2950-3030 rpm, and is adjusted per the Detroit Diesel Series 53 Service Manual.

6.3.2 Shut down the engine according to 6.1.2.

6.3.3 Five minutes after shut-down, check and reset the injector timing and exhaust valve clearance as follows:

Injector timing	-	1.4600 ± 0.0035 inch
Valve clearance	-	0.023 to 0.025 inch (hot)

6.4 Initial Power Calibration Check. Full-rack power calibration checks are made in order at 2200, 2500, and 2800 rpm. Engine start-up is in accordance with 6.1.1. The engine is operated at the specified speed until the observed output has stabilized. A coolant jacket-out temperature of 170° ± 2°F is maintained through calibration checks. The parameters shown below must be within specified limits.

Calibration Parameter	2200	2500	2800
Minimum Observed Output, lb-ft (Bhp)	566(237)	557(265)	529(282)
Normal Oil Gallery Pressure, psi	- - - - - - -	40-60	- - - - - - -
Minimum Oil Gallery Pressure, psi	30	30	30
Minimum Air Box Pressure, psi	2-2.5	2.5-3.9	2.9-4.4
Maximum Air Inlet Restriction, in. H_2O	4	5	8
Maximum Blowby Pressure, in. H_2O	3	3.5	4
Maximum Exhaust Back Pressure, in. Hg	2.1	2.7	2.7
Normal Fuel Pressure, psi	- - - - - - -	45-70	- - - - - - -
Minimum Fuel Pressure, psi	- - - - - - -	35	- - - - - - -

6.5 Shake-Down Run. Immediately following the 2800 rpm power calibration check, the engine is operated for a period of five hours at 2800 rpm and 469 lb-ft dynamometer load (250 BHp) maintaining a coolant jacket-out temperature of 170 ± 2°F. The test parameter data listed in 7.12.1 shall be recorded hourly during the shake-down run.

6.6 Final Power Calibration Check. Following the shake-down run, full-rack power calibration checks shall be made in accordance with 6.4. On completing the 2800 rpm power check, the engine will be shut-down in accordance to 6.1.2 and an airbox inspection performed (see 7.9).

6.7 Oil Flush Run. Drain the reference oil and add 20 quarts of test oil. Run the engine for 30 minutes at 1200 rpm and 30 lb-ft load. Oil flush is not necessary if the test oil is the reference oil.

7. TEST PROCEDURE

7.1 Oil Drain. After oil flush shut-down, and while the oil is still warm, drain the oil and remove the oil filter. Perform the initial airbox inspection.

7.2 Oil Charge. Weigh-in a new oil filter and sufficient test oil to bring the sump level to the full mark on the dipstick gage (approximately twenty-four quarts). Crank the engine long enough to stabilize the oil pressure (approximately 10 seconds), wait five minutes and recheck the oil level.

7.3 Full Load Performance Determination. Conduct a full load (full rack) performance determination measuring engine dynamometer load, brake horsepower (BHp), and brake specific fuel consumption (BSFC) at 200 rpm intervals between engine speeds of 1800 and 2800 rpm. Record all data as per 7.12.1.

7.4 Test Duration. The test consists of 240 hours of operation at prescribed test conditions. Interim oil adjustments, airbox inspections, and oil samplings are made on the following schedule:

Operation	0	20	40	60	80	100	120	140	160	180	200	220	240
Oil Adjustments	-	X	X	X	X	X	X	X	X	X	X	X	-
Oil Sampled	X	X	X	X	X	X	X	X	X	X	X	X	X
Airbox Inspected	X	-	-	X	-	-	X	-	-	X	-	-	-
Oil Change	X	-	-	-	-	-	X	-	-	-	-	-	-
Air Filter Change	-	-	-	-	-	-	*	-	-	-	-	-	-

X indicates adjustment, sampling or inspection to be performed at given test time.

* As needed.

7.5 Test Cycle Description. The endurance test consists of repeating a four-mode, five-hour operating cycle four times daily for a total of 20 hours. The engine is then shut down for a period of four hours after which the daily cycle is repeated. The five-hour operating cycle (shown below) consists of: 0.5 hour at engine idle followed by 2.0 hours at maximum power, followed by 0.5 hour at engine idle followed by 2.0 hours at maximum torque. The 20-hour endurance cycle is conducted for 12 days without interruptions longer than three days.

Endurance Test Operating Cycle

Period	Mode	Time, hrs	Load, %	Speed, rpm	Jacket-Out Temp, °F
1	Idle	0.5	0	675 ± 10	110
	Max Power	2	100	2800 ± 10	170
	Idle	0.5	0	675 ± 10	110
	Max Torque	2	100	2200 ± 10	170
2	Idle	0.5	0	675	110
	Max Power	2	100	2800	170
	Idle	0.5	0	675	110
	Max Torque	2	100	2200	170
3	Idle	0.5	0	675	110
	Max Power	2	100	2800	170
	Idle	0.5	0	675	110
	Max Torque	2	100	2200	170
4	Idle	0.5	0	675	110
	Max Power	2	100	2800	170
	Idle	0.5	0	675	110
	Max Torque	2	100	2200	170
5	Shutdown	4	0	0	

7.6 Operating Conditions. The engine shall be operated under the following conditions:

Operating Condition	Limits		
	Max Power Mode	Max Torque Mode	Idle Mode
Speed, rpm	2800 ± 10	2200 ± 10	675 ± 10
Fuel Flow, lb/hr	117 min.	96 min.	NS

Operating Condition	Limits Max Power Mode	Max Torque Mode	Idle Mode
Obs BHp Output	300±5	265±5	NS
Jacket-out, °F	170 ± 2	170 ± 2	110 ± 5
Coolant ΔT, °F	8 - 12	8 - 12	2 - 6
Inlet Air, °F	90 ± 5	90 ± 5	90 ± 5
Oil Sump, °F	250 max	250 max	NS
Fuel Temp at Filter	95 ± 5	95 ± 5	NS
Fuel Pressure, range	35 - 70	35 - 70	NS
Compressor Suction, clean filter, inches water	8.0 max	NS	NS
Compressor Suction, dirty filter, inches water	10.0 max	NS	NS
Exhaust Back Pressure (after turbo), inches Hg max	2.7	2.1	NS
Blowby Pressure, inches water	4.0 max*	NS	NS
Oil Pressure, psi	30 min	30 min	5 min

* = Blowby pressure greater than 4 inches of water constitutes test shutdown for inspection.
NS = Not Specified

7.7 Used Oil Sampling. Take a 8 fluid ounce sample of oil at the oil filter housing according to the schedule specified in 7.4. This is done with the engine idling prior to the scheduled shut-down and oil adjustment. If fuel dilution (greater than 5%) is detected in the oil, the fuel leak should be repaired and the oil changed before the test continues.

7.8 Oil Adjustment and Oil Change.

7.8.1 Shut down the engine according to 6.1.2. Note that oil samples must be taken during the 5 minute idling period (see 7.7).

7.8.2 Make oil adjustments according to the schedule of 7.4 by adding a weighed amount of test oil to the sump, bring the level to the full mark on the dipstock. Maintenance of an oil log sheet is required. If the oil level is below add halfway (10 hours) through the period, weight and add roughly a gallon of oil so that the engine can finish the period safely. If oil temperature exceeds 250°F, remove and clean the oil heat exchanger. Oil consumption should not exceed 0.75 lb/hr or the test shall be considered invalid.

7.8.3 After the 120-hour oil sample is taken, the engine is shutdown according to 6.1.2. The oil is drained from the oil filter housing and the engine crankcase. A new charge of test oil and a new oil filter are installed per 7.2. The air cleaners are also changed at this time.

7.9 Airbox Inspections. Four airbox inspections shall be made as specified in 7.4. The zero-hour inspection is made at the completion of the final power check and prior to the installation of test oil. Observations made at each airbox inspection must be recorded and included in the final engine inspection. The areas inspected, performance levels noted and means of inspection shall be as follows:

Area Inspected	Performance Level Noted	Means of Inspection
Inlet Ports	Percent Plugging	Visual
Piston Skirt	Tinplate melting	Visual
	Scoring	
	Burning	
Ring Lands	Carbon Deposits	Visual
Rings	Freedom	Blunt Probe
	Face Scuffing	and
	Face Burning	Visual
Cylinder Liner	Scuffing(1)	Illuminated
	Scoring	and Magnifying
	Bridge Cracking(2)	Borescope
	Glazing	Visual

(1) Scuffing shall be described in terms of degree (light, medium and heavy) and in terms of area (thrust, anti-thrust, front and rear). Severe scuffing constitutes a test shutdown.
(2) Bridge cracking constitutes a test shutdown.

7.10 Full Load Performance Determination. Immediately following the final endurance cycle, conduct a full load (full rack) performance determination in the same manner as described in 7.3 (Before Test).

7.11 Final Oil Drain. Shut down engine as outlined in 6.1.2. Let the engine stand for five minutes, then drain the crankcase and oil filter housing. Weigh and record the quantity of oil drained, the oil filter, and the blowby can.

7.12 Data Recording.

7.12.1 The following data shall be recorded once during each idle mode and twice during each power and torque mode.

Operator
Date
Time
Test Hours
Engine Speed, rpm
Load, lb-ft
Fuel Rate, lb/hr
BSFC, lb/bhp-hr
Observed Output, BHp
Temperatures, °F
  Exhaust Manifolds
  Turbocharger exit
  Coolant jacket-in
  Coolant jacket-out
  Oil Sump
  Fuel at Filter
  Compressor Inlet Air
  Airbox
  Ambient Air (wet/dry bulb)

Pressures
Intake vacuum, in. H_2O
Exhaust Turbocharger exit, in. Hg
Exhaust Manifolds, psi
Compressor Discharge, psi
Blower Discharge (Airbox), psi
Transfer pump, psi
Oil Gallery, psi
Blowby, in. H_2O
Barometer, in. Hg.

7.13 Problems Encountered During Test.

7.13.1 High Blowby. Blowby pressure greater than four inches of water constitutes test shutdown for inspection. If the problem appears to be caused by lubricant-related ring wear, then the test should be terminated. Severe problems may be present at blowby pressures less than four inches of water.

7.13.2 Liner Scuffing-Ring Wear. Liner scuffing-ring wear is generally accompanied by high blowby pressures. This condition generally requires test termination. In the case that, before 41 test hours, one liner exhibits severe scuffing while all others exhibit normal wear, that liner-piston-ring set may be replaced and the test continued. The removed parts should be rated but not included in reported averages. Removed liners should exhibit 30% or greater overall scuffing. A fresh oil charge may be used in this instance. Appropriate notations should appear in the test report. Engine oil iron content is also a good indication of ring wear and scuffing.

7.13.3 Visually Observed Scuffing. If severe liner scuffing is observed during the airbox inspections, and that scuffing is judged to be of a progressive nature, then the test should be terminated. Severe liner scuffing can lead to liner o-ring melting and subsequent catastrophic engine failure. Progressive liner scuffing is generally accompanied by high blowby and rapidly increasing engine oil iron content.

7.13.4 Fuel Dilution. If a fuel concentration greater than five percent by weight is detected in the lubricant, the fuel leak should be repaired and the oil changed before the test continues. Fuel crossover lines are generally at fault in this case. Appropriate notations should appear in the test report.

7.13.5 Coolant Dilution. If coolant is detected in the lubricant, the leak should be repaired and the oil changed before the test continues. Appropriate notations should appear in the test report. In order to avoid coolant dilution when cylinder heads are removed the following procedure should be used;

1. Drain lubricant.
2. Drain coolant.
3. Perform desired work taking care to minimize coolant drainage into sump.
4. Flush oil passages by pouring new oil down exposed oil drain holes.
5. Reinstall head(s).

6. Refill with original oil.
7. Refill coolant system.

7.13.6 High Oil Temperature. Oil sump temperatures greater than 250°F generally indicate that the oil-water heat exchangers need cleaning. If after cleaning, the sump temperature remains high, then the test should be halted until the problem is corrected.

7.13.7 Loss of Power.

7.13.7.1 Faulty Injectors. Poor engine performance during the test may be caused by worn, sticking, broken or leaking injectors. Injectors may be replaced at any point in the test.

7.13.7.2 Valve Distress. Poor engine performance caused by exhaust valve distress (burning) constitutes test termination. No exhaust valve replacement is allowed. Exhaust valve stem breakage constitutes test termination, but is not considered lubricant-related failure.

7.13.7.3 Mechanical Problems. Poor engine performance caused by faulty turbochargers, blowers, misadjusted injectors, etc., may be corrected by component replacement and/or adjustment. Appropriate notations should appear in the test report.

7.13.8 High Oil Consumption. High oil consumption (0.75 lb/hr) is generally caused by cracked piston pin retainers or worn oil control rings. Cracked piston pin retainers may be replaced at any point in the test. One set of oil control rings may be replaced before 40 hours of test operation if they appear to be wearing abnormally and causing high oil consumption. If the average oil consumption during the test is greater than 0.75 lb/hr, the test will be considered invalid.

7.13.9 Leaks. Lubricant or coolant leaks should be corrected during the course of the test.

8. EVALUATION OF RESULTS

8.1 Part Ratings.

8.1.1 Preparation for Rating. Pistons and cylinder liners are removed from the engine. Care must be taken to avoid disturbing engine deposits during disassembly. Pistons and cylinder liners are numbered on the thrust side. Using a hydraulic press, split the cylinder liners in half along a longitudinal plane separating the thrust and anti-thrust sides. Any engine not completing the full 240-hour test must be inspected for signs of misassembly before a failure may be termed "lubricant-related."

8.1.2 Piston Ratings. Using the terminology of 8.1.5, the CRC Diesel Engine Rating Manual No. 5, and the proposed CRC Rating System for Diesel Engine Deposits (First Draft), rate the pistons for the following:

Ring groove carbon filling, % ring supporting carbon, and
Weighted Total Demerit (WTD)

Skirt lacquer
Ring sticking
Oil Control Ring Groove Lacquer
Ring Face Condition

8.1.3 Cylinder Liner Ratings. Using the terminology of 8.1.5 and CRC Diesel Engine Rating Manual No. 5, rate the cylinder liners for the following:

Intake Port Restriction
Scuffing (percent fire ring travel area)
Glazing (percent fire ring travel area)
Lacquer

8.1.4 Other Ratings. Combustion chamber deposits in the cylinder head and in the piston crowns shall be rated in terms of texture and depth. Exhaust valves, camshaft lobes, rocker arms, tappets/roller-followers, exhaust valve bridges, crankshaft journals and main/connecting rod bearing inserts will also be rated. Crankshaft main bearing journals and bearings need only be rated at major rebuilds. Any unusual deposits or part condition shall be noted.

8.1.5 Rating Terminology. Ratings shall be made using the CRC Diesel Engine Rating Manual No. 5 and terminology defined as follows:

Scuffing - Mechanical disturbance of a rubbing surface with no appreciable surface roughness to feel.

Scoring - Mechanical disturbance of a rubbing surface with a definite surface roughness in line with motion characterized by the transfer of metal by dragging which results in progressive deterioration.

Seizure - Sticking together of two surfaces characterized by the presence of small particles of material which have become welded to the surface.

Glazing - Continuous removal of surface material resulting in a mirror-polished appearance of very low micro-finish.

Burning - Removal of metal from sealing surface (ring face) to form leakage paths.

Lacquer - A thin varnish-like deposit which cannot be removed by wiping with saturated solvents, such as petroleum naphtha, but is soluble in lacquer solvents, such as benzene and acetone.

Carbon - A firm deposit composed primarily of hydrocarbon residue which has thickness, volume and texture (hard, medium, and soft).

Ash - Residue of combustion, inorganic in nature.

Ring Sticking - The relative degree of freedom of a piston ring in its groove as removed from the engine.

8.2 Lubricant Analyses. Test lubricant degradation over the 240-hour test period shall be determined and reported as shown in Appendix G.

8.3 Data Presentation.

8.3.1 Rating Data. Suitable forms for recording data are shown in Appendix F; all information shown on these forms shall be furnished with the test report.

8.3.2 Operating Data. Mean and standard deviation operating data for the maximum power mode and the maximum torque mode shall be reported, together with the average oil consumption. Plotted full-load power performance data before and after test will be included. This will show BHp, BMEP, and BSFC at full rack plotted as a function of engine speed.

8.3.4 Build-up and Wear Measurement Data. Suitable forms for presenting the build-up and wear measurements are presented in Appendix H.

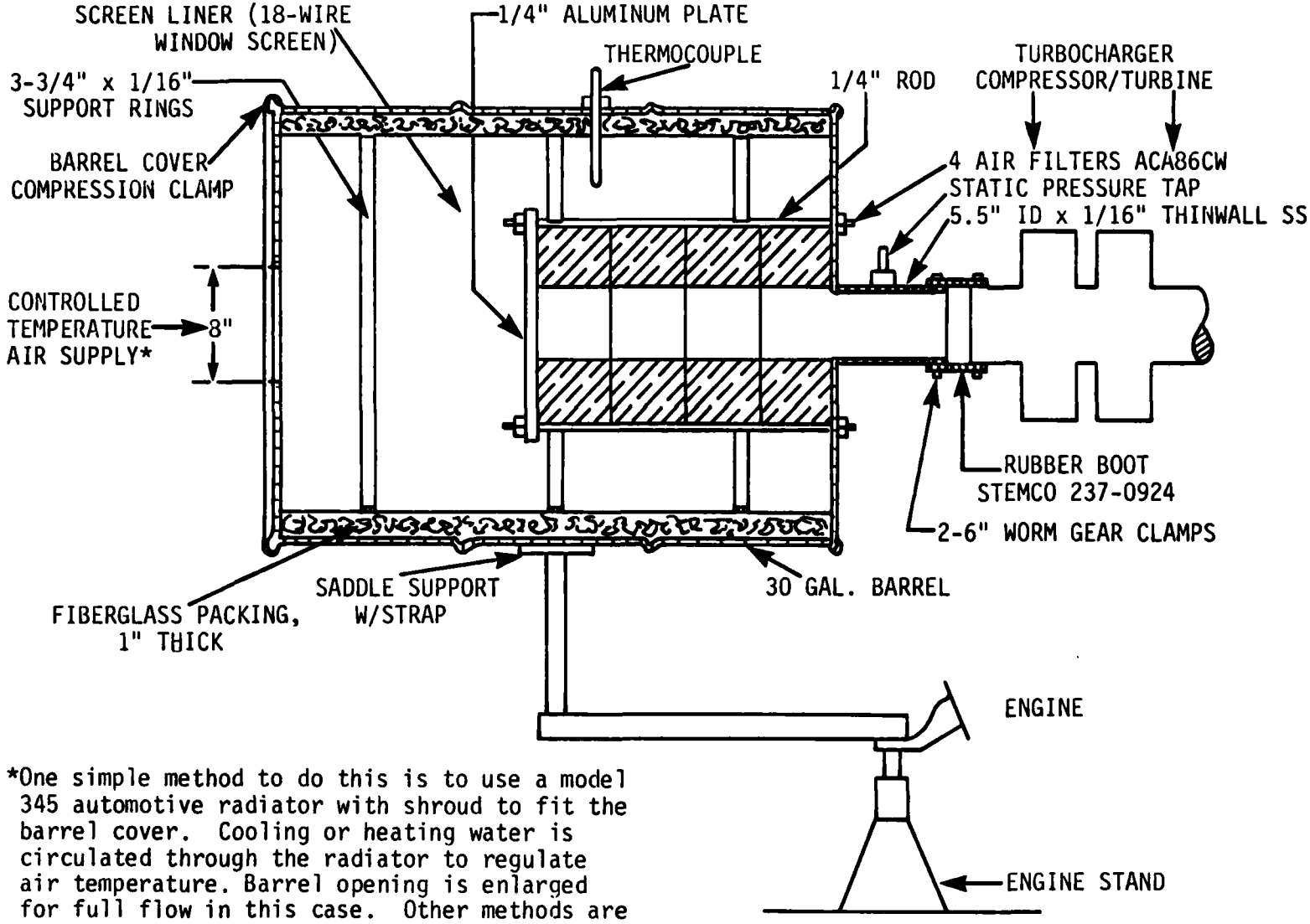
8.3.5 Photographic Data. Color photographs of each piston and split cylinder liner showing both thrust and anti-thrust sides shall be presented. All photographs shall be on a white background and shall be clearly marked giving cylinder number, right or left, and thrust or anti-thrust. Photographs of piston ring surfaces (opposite gap) and cylinder head deposits shall also be presented. Pictures shall be presented in the following order and manner:

1. Piston rings 1-L and 1-R shall be on the same page. Apparent ring diameter shall be equal to or greater than four inches. Rings shall be photographed with a space between each ring and in the top to bottom order of 1,2,3,4,5,6,7. Lighting should emphasize ring distress and attempts should be made to eliminte extraneous reflections from the ring surfaces.
2. Piston 1-L thrust and antithrust shall be presented on the same page. Apparent piston height shall be equal to or greater than 4 inches. The thrust photograph should be the left most of the two photographs in all instances.
3. Piston 1-R thrust and antithrust shall be presented on the same page.
4. Liner 1-L thrust and antithrust shall be presented on the same page. Apparent liner height shall be equal to or greater than six inches.
5. Liner 1-R
6. Rings 2-L and 2-R
7. Piston 2-L
8. Piston 2-R
9. Liner 2-L
10. Liner 2-R
11. Rings 3-L and 3-R
12. Piston 3-L
13. Piston 3-R
14. Liner 3-L
15. Liner 3-R
16. The left and right cylinder heads shall be displayed on the same page. Apparent head length shall be equal to or greater than five inches. Heads shall be displayed horizontally with cam followers topmost. Combustion chambers should be labeled 1R, 2R, etc.

9. PRECISION

9.1 A reference test is required when a new engine or a new test stand is put into service for the first time, or when an established facility re-installs a test stand. To maintain severity level, reference tests on each engine are required every thirteen tests. This implies that twelve candidate oils may be tested between reference runs on a single engine. An engine is defined as a block and any buildup constitutes a test. Each test stand must be referenced every ninth test or six months, whichever comes first. This implies that each stand may run eight candidate oils between reference tests or that six months may elapse between reference runs. Reporting of an engine's or stand's reference history is optional.

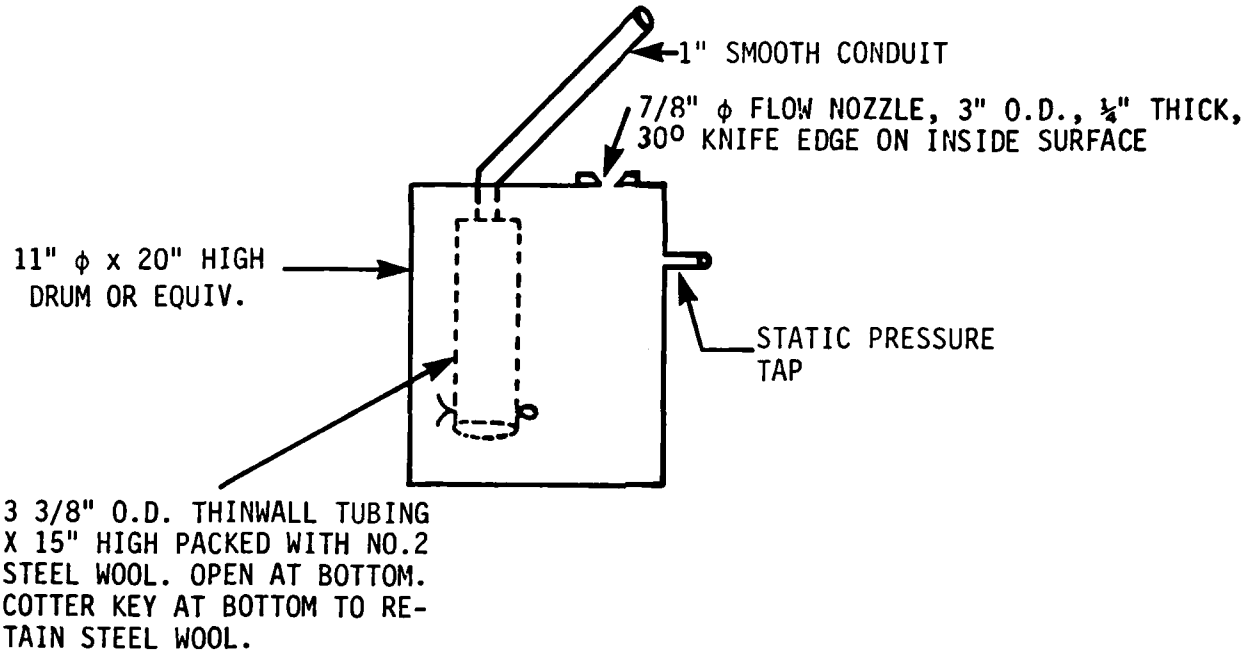
APPENDICES



*One simple method to do this is to use a model 345 automotive radiator with shroud to fit the barrel cover. Cooling or heating water is circulated through the radiator to regulate air temperature. Barrel opening is enlarged for full flow in this case. Other methods are acceptable.

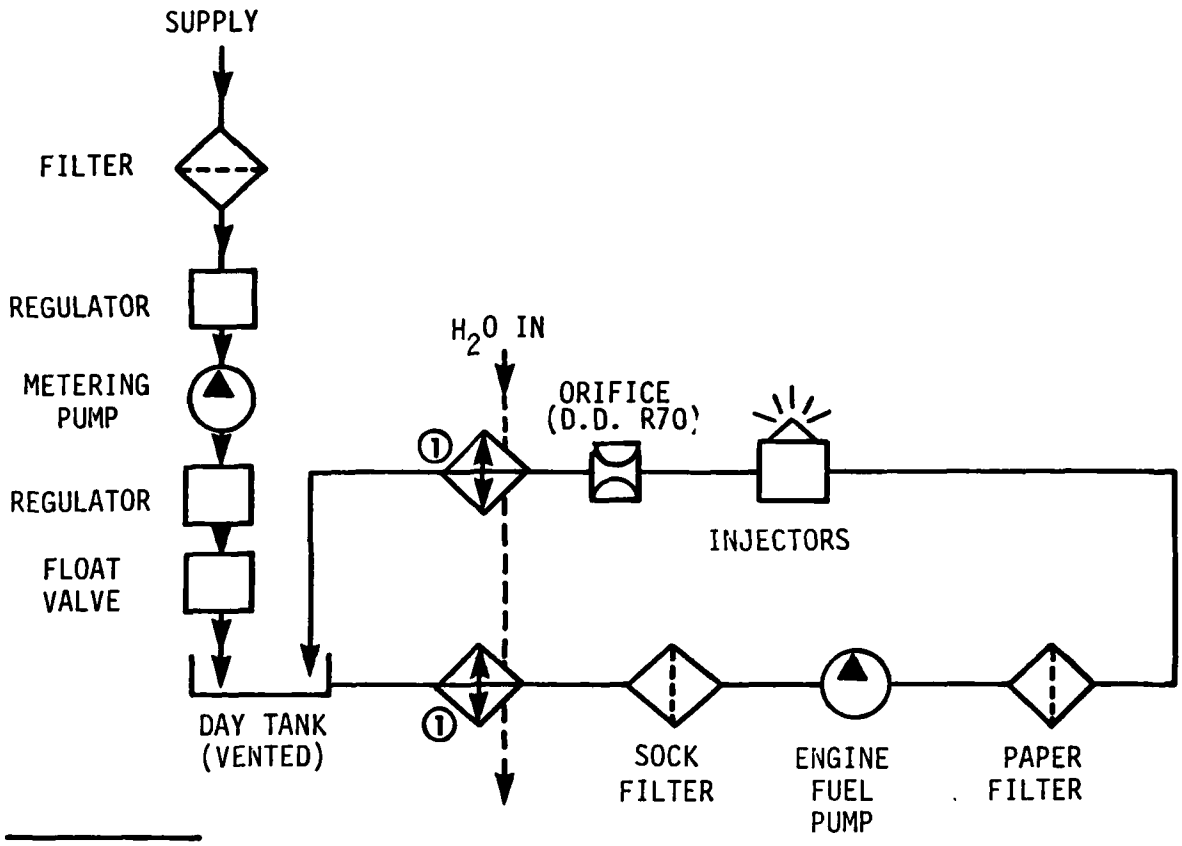
APPENDIX B

BLOWBY SURGE TANK



APPENDIX C

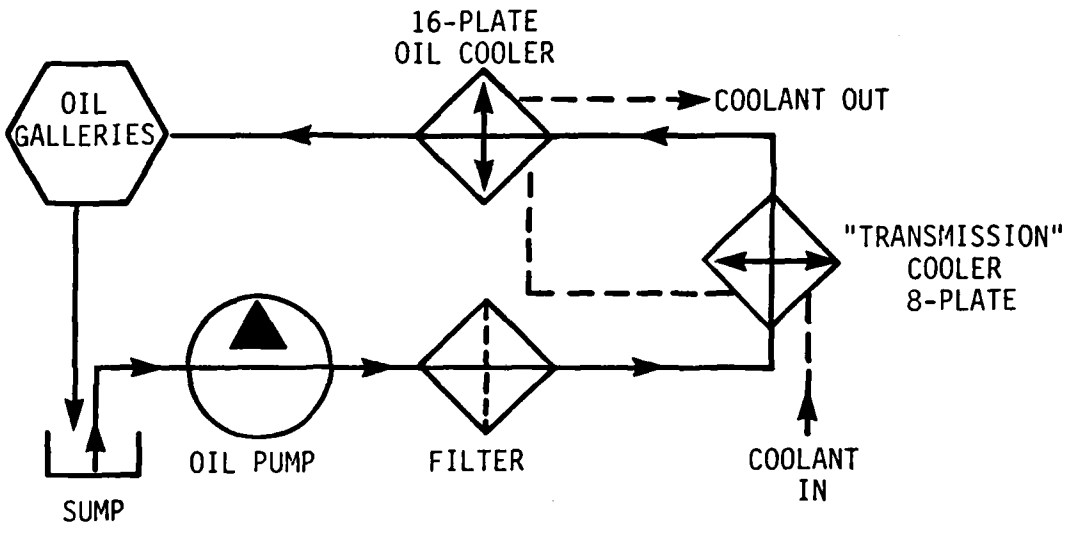
FUEL SYSTEM SCHEMATIC



① AMERICAN STANDARD BCF 5-030-03-014-003 HEAT EXCHANGERS OR EQUIVALENT

APPENDIX D

OIL SYSTEM SCHEMATIC



APPENDIX E

BEFORE TEST AND AFTER TEST

DATA SHEETS

TEST NO._____

BLOCK NO._____

HEAD NO._____ L

_____ R

DATE STARTED_____

DATE FINISHED_____

LUBRICANT_____

FUEL_____

DATE _____ TEST NO _____ TECHNICIAN _____

LUBRICANT _____ FUEL _____

6V53T PISTON RING CLEARANCES

		BEFORE TEST End Gap*	Side	AFTER TEST End Gap
1L	1			
	2			
	3			
	4			
	5			
	6			
	7			
2L	1			
	2			
	3			
	4			
	5			
	6			
	7			
3L	1			
	2			
	3			
	4			
	5			
	6			
	7			

		BEFORE TEST End Gap	Side	AFTER TEST End Gap
1R	1			
	2			
	3			
	4			
	5			
	6			
	7			
2R	1			
	2			
	3			
	4			
	5			
	6			
	7			
3R	1			
	2			
	3			
	4			
	5			
	6			
	7			

Build-Up Engine Measurement Specifications (inches)

	End Gap	Side Clearance
No. 1, Fire Ring	0.020-0.046	0.003-0.006
No. 2, Compression Ring	0.020-0.036	0.007-0.010
No. 3 & 4, Compression Rings	0.020-0.036	0.005-0.008
No. 5, 6 & 7, Oil Rings	0.010-0.025	0.0015-0.0055

*All end gap measurements taken in 3.8750" I.D. measuring jig.

DATE_____ TEST NO._____ TECHNICIAN_____

LUBRICANT_____ FUEL_____

6V53T CYLINDER LINER INSIDE DIAMETER (INSTALLED)

Measuring Gauge Set at 3.8750 inches.

Numbers given are ten thousandths of an inch.

		BEFORE TEST			AFTER TEST		
		Top *	Middle *	Bottom *	Top	Middle	Bottom
1L	T - AT						
	F - B						
2L	T - AT						
	F - B						
3L	T - AT						
	F - B						
1R	T - AT						
	F - B						
2R	T - AT						
	F - B						
3R	T - AT						
	F - B						

*5/8", 5", and 9" below block surface, respectively.

Build-Up Engine Measurement Specifications (inches)

Cylinder Liners (installed

Taper	0.0015	Max
Out-of Round	0.0015	Max
Inside Diameter	3.8752-3.8767	

DATE_____ TEST NO_____ TECHNICIAN_____

LUBRICANT_____ FUEL_____

BEFORE TEST

6V53T PISTON - CYLINDER LINER CLEARANCE

All measurements are in inches unless otherwise indicated.

	CYLINDER LINER I.D.		PISTON SKIRT O.D.	CLEARANCE	
	MIN.	MAX		MIN.	MAX
1L					
2L					
3L					
1R					
2R					
3R					

Build-Up Engine Measurement Specifications (inches)

Piston to Liner Fit	0.0061-0.0098
Piston Skirt O.D.	0.38669-3.8691
Cylinder Liner I.D. (installed)	3.8752-3.8767

DATE_____ TEST NO._____ TECHNICIAN_____

LUBRICANT_____ FUEL_____

6V53T PISTON PIN TO PISTON BUSHING CLEARANCE

	BEFORE TEST			AFTER TEST		
	PIN	BUSHING	CLEARANCE	PIN	BUSHING	CLEARANCE
1L	___	_____	_____	___	_____	_____
2L	___	_____	_____	___	_____	_____
3L	___	_____	_____	___	_____	_____
1R	___	_____	_____	___	_____	_____
2R	___	_____	_____	___	_____	_____
3R	___	_____	_____	___	_____	_____

6V53T PISTON PIN TO ROD BUSHING CLEARANCE

	BEFORE TEST			AFTER TEST		
	PIN	BUSHING	CLEARANCE	PIN	BUSHING	CLEARANCE
1L	___	_____	_____	___	_____	_____
2L	___	_____	_____	___	_____	_____
3L	___	_____	_____	___	_____	_____
1R	___	_____	_____	___	_____	_____
2R	___	_____	_____	___	_____	_____
3R	___	_____	_____	___	_____	_____

Rebuild Engine Measurement Specifications (inches)

Piston Pin Outside Diameter	1.3746 - 1.3750
Piston Bushing Inside Diameter	1.3775 - 1.3780
Pin-to-Piston Bushing Clearance	0.0025 - 0.0034
Rod Bushing Inside Diameter	1.3760 - 1.3765
Pin-to-Rod Bushing Clearance	0.0010 - 0.0019

DATE_____ TEST NO._____ TECHNICIAN_____

LUBRICANT_____ FUEL_____

6V53T BLOCK BORE DIAMETER

Measuring Gauge Set at 4.3560 inches.

Numbers given are ten thousandths of an inch.

			BEFORE TEST	AFTER TEST
1L	T-AT	Top *		
		Bot **		
	F - B	Top		
		Bot		
2L	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
3L	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
1R	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
2R	T-AT	Top		
		Bot		
	F - B	Top		
		Bot		
3R	A-AT	Top		
		Bot		
	F - B	Top		
		Bot		

Build-up Engine Measurement Specifications (inches)

Block Bore

Taper	0.0015	Max	*7 1/2" below block surface
Out-of Round	0.0015	Max	**8 1/2" below block surface
Inside Diamenter	4.3565-4.3575	New	
	4.3595	Max	

DATE_____ TEST NO_____ TECHNICIAN_____

LUBRICANT_____ FUEL_____

6V53T VALVE DEPTH (BEFORE TEST)

	LEFT SIDE			RIGHT SIDE	
1L	_____	_____	1R	_____	_____
	_____	_____		_____	_____
2L	_____	_____	2R	_____	_____
	_____	_____		_____	_____
3L	_____	_____	3R	_____	_____
	_____	_____		_____	_____

MAJOR REBUILD ONLY

CRANKSHAFT THRUST WASHER THICKNESS (BEFORE TEST)

1 _____ _____

2 _____ _____

3 _____ _____

4 _____ _____

Crankshaft End Play (Before Test)_____

Oil Pump Clearances (Before Test)

Clearance Between Rotors_____

Clearance Between Rotor and Housing_____

Build-Up Engine Measurement Specifications (inches)

Valve Head Relation to Cylinder Head	Flush to 0.024 Below Cylinder Head Surface
Crankshaft Thrust Washer Thickness	0.1190 to 0.1220
Crankshaft End Play	0.0040 to 0.0110
Oil Pump Clearance Between Rotors	0.0040 to 0.0110
Oil Pump Clearance Between Rotor and Housing	0.0010 to o.0035

DATE_____ TEST NO._____ TECHNICIAN_____

LUBRICANT_____ FUEL_____

6V53T MAIN BEARING SHELL AND BEARING JOURNAL DIAMETERS AND CLEARANCES

MAJOR REBUILD ONLY

	BEFORE TEST						AFTER TEST			
	Bearing Journals		Bearing Shells		Clearances		Bearing Journals		Bearing Shells	
	A*	B	F	BA	Min.	Max	A	B	F	BA
1										
2										
3										
4										

*A: Micrometer anvil parallel to weights

B: Micrometer anvil perpendicular to weights

F: Front

BA: Back

6V53T CONNECTING ROD BEARING SHELL AND BEARING JOURNAL DIAMETERS AND CLEARANCES

	BEFORE TEST						AFTER TEST			
	Bearing Journals		Bearing Shells		Clearances		Bearing Journals		Bearing Shells	
	A*	B	F	BA	Min.	Max	A	B	F	BA
1L										
2L										
3L										
1R										
2R										
3R										

Build-Up Engine Measurement Specifications (inches)	NEW	LIMIT
Main Bearing Journal Diameter	3.4990 to 3.5000	
Main Bearing Shell Inside Diameter (vertical axis)	3.5030 to 3.5040	
Main Bearing Shell to Journal Clearance	0.0010 to 0.0040	0.0060
Connecting Rod Bearing Journal Diameter	2.7490 to 2.7500	
Connecting Rod Bearing Shell Inside Diameter (vertical axis)	2.7511 to 2.7500	
Connecting Rod Bearing Shell to Journal Clearance	0.0011 to 0.0041	0.0060

DATE_____ TEST NO._____ TECHNICIAN_____

LUBRICANT_____ FUEL_____

6V53T Camshaft Bearing Shell and Bearing Journal Diameters
Bearing Shell Measuring Gauge Set at 2.175 inches

MAJOR REBUILD ONLY

LEFT CAMSHAFT

	BEFORE TEST				AFTER TEST			
	Journal		Bearing		Journal		Bearing	
1								
2								
3								
4								

RIGHT CAMSHAFT

	BEFORE TEST				AFTER TEST			
	Journal		Bearing		Journal		Bearing	
1								
2								
3								
4								

MAJOR REBUILD ONLY

Build-Up Engine Measurement Specifications (inches)

Camshaft Bearing Journal Diameter	2.1820 to 2.1825
Camshaft Bearing Shell Inside Diameter	2.1870 to 2.1880
Camshaft Bearing Shell to Journal Clearance	0.0045 to 0.0060

TEST NO. _____

6V-53T 240-HOUR CHECKLIST

Initials	Task
	Fill out page 1 of Before Test and After Test Data Sheets.
	Measure and record ring end gap and side clearance.
	Measure and record cylinder liner inside diameter (installed).
	Measure and record piston-cylinder liner clearance.
	Measure and record piston pin-piston bushing clearance and piston pin-rod bushing clearance.
	Measure and record block bore diameter.
	Measure and record valve depth.
	Check valve clearances and replace valves and guides out of specification. Replace valves after three runs.
	Measure and record connecting rod bearing shell and bearing journal diameters and clearances.
	For major rebuilds only - measure and record oil pump clearances, crankshaft thrust washer thickness and crankshaft end play.
	For major rebuilds only - measure and record main bearing shell and bearing journal diameters and clearances.
	For major rebuilds only - measure and record camshaft bearing shell and bearing journal diameters.
	Calibrate tachometer.
	Calibrate flowmeter.
	Calibrate load system.
	Calibrate temperature indicators.
	Calibrate pressure indicators.
	Fill engine with reference oil.
	Break in engine.
	Adjust governor, injector timing, and valve clearance.
	Run and record initial power calibration check.
	Run shake down.
	Run final power calibration check.
	Perform airbox inspection.
	Drain oil and add five gallon flush oil.
	Run flush cycle - 30 minutes at 1200 rpm and 30 #FT.
	Drain oil.
	Perform airbox inspection.
	Weigh new filter, blowby canisters and intial fill.
	Run full load performance determination.
	Run test cycle, weigh samples and adds.
	Perform after-test full load performance determination.
	Drain and weigh oil, filter, and blowby cans.
	Measure and record cylinder liner inside diameter.
	Disassemble engine stamping liners and pistons.
	Measure and record piston pin to piston bushing clearance and piston pin to rod bushing clearance.
	Measure and record connecting rod, bearing shell, and bearing rod journal clearances.
	Major rebuild only - measure and record main bearing shell and bearing journal diameters and clearances.
	Major rebuild only - measure and record camshaft bearing shell and bearing journal diameters.
	Rate engine for deposits.
	Measure and record ring end gap.
	Photograph engine parts.

6V53T 240-HOUR ENDURANCE TEST LUBRICANT CONSUMPTION RECORD

Date Started_____ Test No._____ Fuel_____

Date Finished_____ Lubricant_____

Approximate Consumption (lb)

Weight of Initial Fill		
Weight of 120-hour Fill	+	
Total Weight of Additions	+	
Total Weight of Oil Added	=	
Weight of 120-hour Drain		
Weight of Final Drain	+	
Total Weight of Samples	+	
Total Weight of Oil Removed	=	

		0-120 hr	120-240
Weight of Used Oil Filter			
Weight of New Oil Filter	-		
Weight of Oil in Filter	=		
Total Weight of Oil in Filters	=		

After Test Blowby Can Weight		
Before Test Blowby Can Weight	-	
Total Weight of Oil in Blowby	=	
Total Weight of Oil Added		
Total Weight of Oil Removed	-	
Total Weight of Oil in Filters	-	
Total Weight of Oil in Blowby	-	
Total Weight of Oil Consumed	=	

6V53T 240-HOUR ENDURANCE TEST LUBRICANT CONSUMPTION RECORD
(DOES NOT INCLUDE INITIAL AND 120 HOUR FILLS)

Date Started _____ Test No. _____ Fuel _____

Date Finished _____ Lubricant _____

Test Hour	Technician	Lubricant Additions: Before Add(lb)	Lubricant Additions: After Add(lb)	Lubricant Additions: Change(lb) (= Oil Added)	Lubricant Samples: Bottle Wt(lb)	Lubricant Samples: Sample+ Bottle Wt(lb)	Lubricant Samples: Change(lb) (= Oil Sample)	Lubricant Consumed: Oil Added - Oil Sampled (= Oil Consumed)	Lubricant Consumed: Total Oil Consumed*
20									
40									
60									
80									
100									
120									
140									
160									
180									
200									
220									
240									

Ttl Wt Additions: _____ Ttl Wt of Samples: _____

* During test, average oil consumption is approximated by Total Oil Consumed divided by Test Hour.

APPENDIX F

RATING SHEETS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE _____ RATER _____ DATE _____ PISTON NO. _____

TEST HOURS _____ LABORATORY TEST NUMBER _____

TEST LABORATORY _____ STAND NO. _____ ENGINE NO. _____

LUBRICANT _____ FUEL _____

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN	
		NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4			
		AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON HC	1.00																		
CARBON MHC	0.75																		
CARBON MC	0.50																		
CARBON LC	0.25																		
CARBON VLC	0.15																		
CARBON RATING																			
LACQUER BL	0.100																		
LACQUER DBrL	0.075																		
LACQUER AL	0.050																		
LACQUER LAL	0.025																		
LACQUER VLAL	0.010																		
LACQUER RL	0.001																		
LACQUER RATING																			
CLEAN	0																		
ZONAL RATING																			
LOCATION FACTOR																			
WEIGHTED RATING																			

NOT USED

*WEIGHTED TOTAL DEPOSITS

DETROIT DIESEL 6V-53 EVALUATION

Rating of Engine Deposits and Parts Condition

Oil	- _____	Test Number	- _____
Formula	- _____	Date Test Completed	- _____
Viscosity Grade	- _____	Engine Number	- _____
Fuel	- _____	Test Stand Number	- _____
		Hours Completed	- _____

I. Cylinder Liners

a. Intake Ports

INTAKE PORT PLUGGING

Cylinder No.	Percent Intake Port Restriction
1L	
2L	
3L	
1R	
2R	
3R	
Average	

b. Liner Scuffing

CYLINDER LINER SCUFFING

Percent of Total Ring Travel Area Scuffed

Cylinder No.	Percent Scuffed		% Total Area Scuffed	% Glazed	% Lacquer
	Thrust	Anti-Thrust			
1L					
2L					
3L					
1R					
2R					
3R					
Average					

DETROIT DIESEL 6V-53T EVALUATION

Rating of Engine Deposits and Parts Condition

II. Pistons

a. Condition of Rings in Grooves

Cylinder No.	No. 1 Fire Ring	No. 2	No. 3	No. 4	
1L					
2L					
3L					
1R					
2R					Overall
3R					Average
Average					

* Numbers denote % area ringface burn

b. Piston Ring Groove Carbon, % Filling

Cylinder No.	No. 1 Fire Ring	No. 2	No. 3	No. 4
1L				
2L				
3L				
1R				
2R				
3R				

c. Piston Skirt Rating (Demerit)

Cylinder No.	Thrust	Anti-Thrust
1L		
2L		
3L		
1R		
2R		
3R		

d. Oil Control Ring Grooves (Demerit)

Cylinder No.	Upper	Lower
1L		
2L		
3L		
1R		
2R		
3R		

DETROIT DIESEL 6V-53T EVALUATION

Rating of Engine Deposits and Parts Condition

e. Oil Drain Holes (pistons)

_____

f. Land Deposits

_____

III. *Exhaust Valves - _____

IV. *Combustion Chambers - with exhaust valves

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

V. *Exhaust Ports

_____ _____
_____ _____
_____ _____

VI. Valve Cover, Cylinder Head Decks, and Oil Pan

Covers - _____

Pan - _____

Decks - _____

* Texture in terms of Hard-Medium-Soft Carbon; Depths of A-B-C.

RING STICKING

Test No. _____

Engine Model _____ Serial No. _____ Date _____

Fuel _____ Lubricant _____ Observer _____

Piston Number

Ring No.	1L	2L	3L	1R	2R	3R
1						
2						
3						
4						

Indicate by letter – Free or Sluggish, or by number and letter – percent Pinched (cold stuck) or percent Hot stuck (Pages 6 and 7 of Manual).

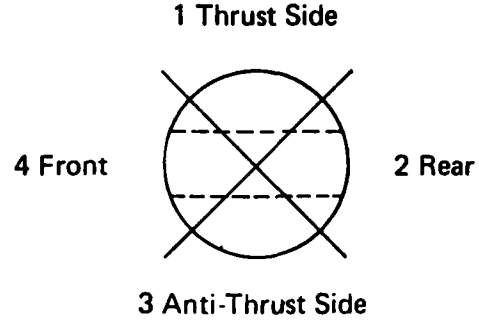
PISTON GROOVE INSIDE DIAMETER–% RING SUPPORTING CARBON

Test No. _____

Engine Model _____ Serial No. _____ Date _____

Fuel _____ Lubricant _____ Observer _____

Piston Ring	Quadrant	Piston Number					
		1L	2L	3L	1R	2R	3R
1	1						
	2						
	3						
	4						
2	1						
	2						
	3						
	4						



VALVE DEPOSITS

Test No._____

Engine Model_____ Serial No._____ Date_____

Fuel_____ Lubricant_____ Observer_____

		Cylinder Number											
		1L		2L		3L		1R		2R		3R	
Head*	INT	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ
	EXH												
Face	INT												
	EXH												
Tulipt	INT												
	EXH												
Stem	INT												
	EXH												

*Carbon and Ash: Use Volume Factor Technique (Pages 5 and 40 through 47 of CRC Manual No. 5).
†Use Chart, Page 21—indicate H, M, or S (Page 5).
Lacquer: Pages 4, 36, and 37.

EXHAUST VALVE SURFACE CONDITIONS

Test No. _____

Engine Model _____ Serial No. _____ Date _____

Fuel _____ Lubricant _____ Observer _____

	1L	2L	3L	1R	2R	3R
Freeness in Guide						
Head						
Face						
Seat						
Stem						
Tip						

See Pages 1, 2, 16 through 23, and 54 through 65 of CRC Manual No. 5.

TAPPETS, CAMS, AND ROCKER ARMS

Test No. _____

Engine Model _____ Serial No. _____ Date _____

Fuel _____ Lubricant _____ Observer _____

			Cylinder Number					
			1L	2L	3L	1R	2R	3R
Tappet Deposit		INT						
		EXH						
Tappet Surface Condition		INJ						
		INT						
		EXH						
Cam Lobes								
Rocker Arms	Tip	INT						
		EXH						
	Bushing	INT						
		EXH						
	Shaft	INT						
		EXH						

Lacquer: Pages 4, 36 and 37 of CRC Manual No. 5
See Pages 1, 2, 16 through 23, and 54 through 65.

SURFACE CONDITION

Test No._____

Engine Model_____ Serial No._____ Date_____

Fuel_____ Lubricant_____ Observer_____

Bearing No.	1	2	3	4	5	6	7
Main—Bearing							
—Journal							
Rod—Bearing							
—Journal							
Piston Pin							
Bushing							

Note surface condition. See pages 1, 2, 16 through 23 and 54 through 65 of Manual.

APPENDIX G

LUBRICANT ANALYSIS

	Test Method	New Oil	Test Hour 20	40	60	80	100	120	140	160	180	200	220	240
Viscosity at 40°C	D 445	X			X			X			X			X
Viscosity at 100°C	D 445	X			X			X			X			X
TAN	D 664	X			X			X			X			X
TBN	D 664	X			X			X			X			X
Pentane B Insolubles	D 893	X			X			X			X			X
Toluene B Insolubles	D 893	X			X			X			X			X
Flash Point	D 92	X												X
Fuel Dilution	D 3524		X					X						X
Fe	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Cu	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Pb	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Cr	a	X	X	X	X	X	X	X	X	X	X	X	X	X
Al	a	X	X	X	X	X	X	X	X	X	X	X	X	X

a = by any of the following methods: AA, XRF, emission spec.

APPENDIX H
6V-53T
TEST NO.:
LUBRICANT:

WEAR MEASUREMENTS

Cylinder Liner Bore Diameter Change*

Cylinder Number

	1L		2L		3L	
	T-AT**	F-B	T-AT	F-B	T-AT	F-B
Top						
Middle						
Bottom						

Cylinder Number

	1R		2R		3R	
	T-AT	F-B	T-AT	F-B	T-AT	F-B
Top						
Middle						
Bottom						

Average Change

	T-AT	F-B
Top		
Middle		
Bottom		

Overall Average Change:

Piston Ring End Gap Change

Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1							
2							
3							
4							
5							
6							
7							

Overall Average Change:

* All dimensions given are in inches and (millimeters).

** T-AT= Thrust -Anti-thrust Direction, F-B= Front-Back Direction

APPENDIX B

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL FUEL

Lubricant AL-12271-L, Test No. 31

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL ENGINE

Test Lubricant: AL-12271-L
Test Fuel: Caterpillar 1-H
Engine Test Number: 31
Date Completed: 28 June 1983

Conducted For

U.S. Army Mobility Equipment Research and Development Command
Materials, Fuels and Lubricants
Fort Belvoir, Virginia

by

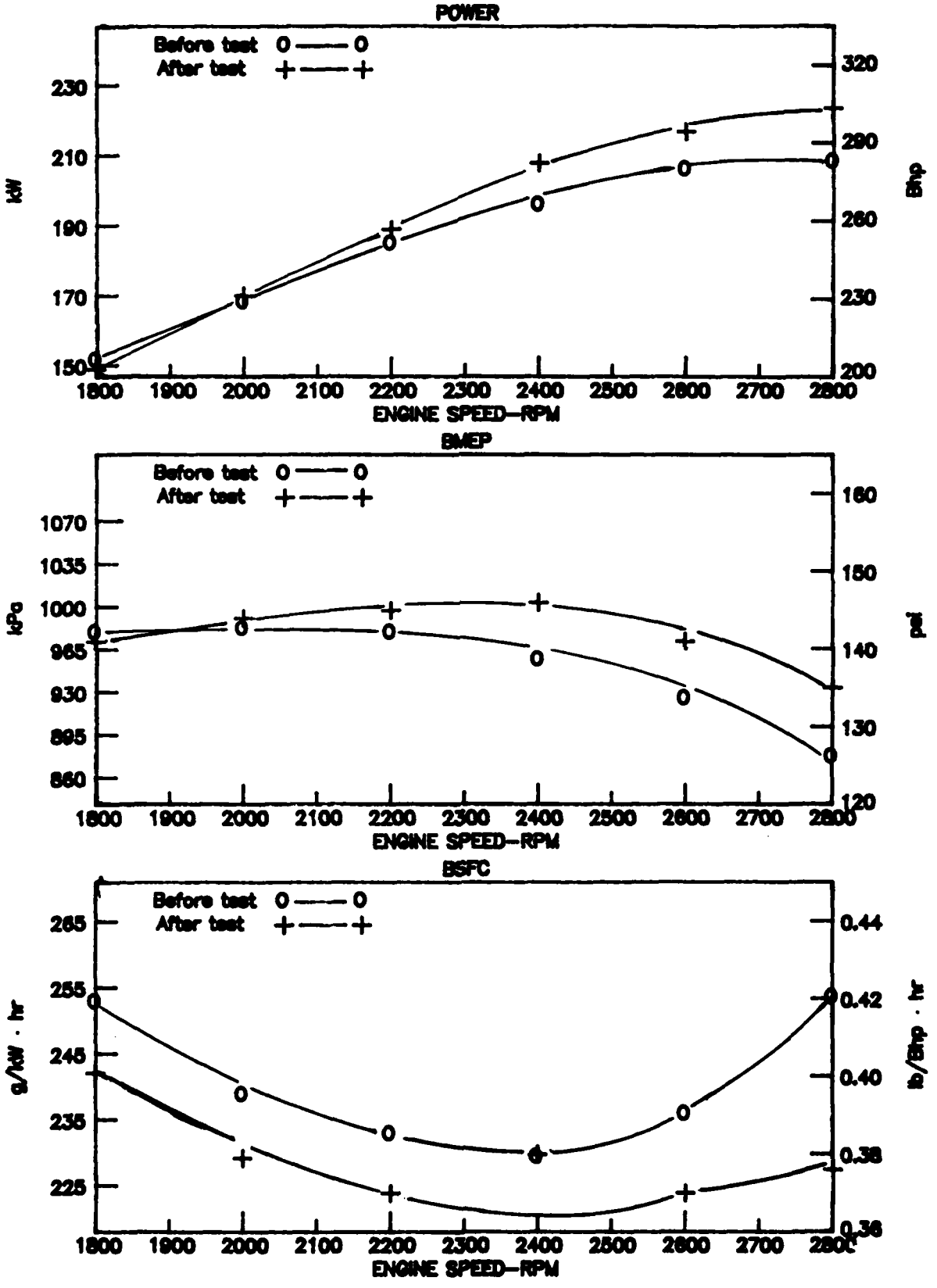
U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

6V-53T
TEST 31
ENGINE REBUILD MEASUREMENTS*
Model Number: 5063-5395
Serial Number: 6D-157211

	Min	Max	Avg	Specified Limits	
Cylinder Block Bore					
Inside Diameter (Bottom)	4.3566(110.658)	4.3582(110.698)	4.3573(110.675)	4.3565(110.655)	- 4.3575(110.681) New - 4.3595(110.731) Max
Out-of-Round	0.0000	0.0010(0.025)	0.0004(0.010)		- 0.0015 (0.038) Max
Taper	0.0000	0.0004(0.010)	0.0002(0.005)		- 0.0015 (0.038) Max
Cylinder Liners (Installed)					
Inside Diameter	3.8754(98.435)	3.8765(98.463)	3.8761(98.453)	3.8752(98.430)	- 3.8767(98.468)
Out-of-Round	0.0000	0.0011(0.028)	0.0003(0.0077)		- 0.0015(0.038) Max
Taper	0.0001(0.003)	0.0006(0.015)	0.0003(0.0077)		- 0.0015(0.038) Max
Piston Diameter (at skirt)	3.8678(98.242)	3.8690(98.273)	3.8683(98.255)	3.8669(98.219)	- 3.8691(98.275)
Piston Skirt to Cylinder Liner Clearance	0.0069(0.175)	0.0086(0.218)	0.0077(0.196)	0.0061(0.155)	- 0.0098(0.249)
Compression Rings					
Gap (No. 1, Fire Ring)	0.030(0.76)	0.036(0.91)	0.034(0.86)	0.020(0.51)	- 0.046(1.17)
Gap (Nos. 2, 3, 4)	0.029(0.74)	0.036(0.91)	0.034(0.86)	0.020(0.51)	- 0.036(0.91)
Ring-to-Groove Clearance					
Top (No. 1, Fire Ring)	0.004(0.10)	0.004(0.10)	0.004(0.10)	0.003(0.08)	- 0.006(0.15)
No. 2, Compression Ring	0.008(0.20)	0.008(0.20)	0.008(0.20)	0.007(0.18)	- 0.010(0.25)
No. 3 and 4, Compression Rings	0.006(0.15)	0.006(0.15)	0.006(0.15)	0.005(0.13)	- 0.008(0.20)
Oil Control Rings, Nos. 5, 6, 7					
Gap	0.015(0.38)	0.020(0.51)	0.017(0.43)	0.010(0.25)	- 0.025(0.64)
Ring-to-Groove Clearance	0.003(0.08)	0.004(0.10)	0.004(0.10)	0.0015(0.038)	- 0.0055(0.140)
Piston Pin					
Pin-to-Piston Bushing Clearance	0.0026(0.066)	0.0030(0.076)	0.0030(0.076)	0.0025(0.064)	- 0.0034(0.086)
Pin-to-Connecting Rod Bushing Clearance	0.0016(0.041)	0.0017(0.043)	0.0017(0.043)	0.0010(0.025)	- 0.0019(0.048)
Connecting Rod Bearing-to-Journal Clearance	0.0024(0.061)	0.0028(0.071)	0.0026(0.067)	0.0011(0.028)	- 0.0041(0.104)
Main Bearing-to-Journal Clearance	0.0039(0.099)	0.0040(0.102)	0.0039(0.099)	0.0010(0.025)	- 0.0040(0.102)
Camshaft Bearing-to-Shaft Clearance	0.0055(0.140)	0.0059(0.150)	0.0057(0.145)	0.0045(0.114)	- 0.0060(0.152)

*Measurements are in inches and (mm)

6V-53T 240-HOUR TRACKED VEHICLE CYCLE
BEFORE AND AFTER TEST 31 PERFORMANCE DATA



6V-53T
240-HOUR TRACKED VEHICLE ENDURANCE TEST
TEST 31
OPERATING CONDITIONS SUMMARY

Lubricant: AL-12271-L Fuel: Caterpillar 1-H

	Maximum Power Mode (2800 RPM)		Maximum Torque Mode (2200 RPM)	
	Mean	Standard Deviation	Mean	Standard Deviation
Engine Speed, rpm	2802	3.05	2204	3.97
Torque, ft-lb (N-m)	517(701)	3.8(5.1)	580(786)	3.01(4.1)
Fuel Consumption, lb/hr(kg/hr)	104.6(47.4)	0.94(0.42)	88.96(40.35)	0.67(0.30
Observed Power, Bhp(kW)	275.3(205.6)	2.09(1.56)	242.7(181.3)	1.43(1.07)
BSFC, lb/Bhp-hr(g/kW-hr)	0.380(230.79)	0.004(2.31)	0.367(222.6)	0.002(1.39)
Temperatures, °F(°C)				
Exhaust before Turbo	905(485)	30.10(16.7)	901(483)	26.4(14.7)
Exhaust after Turbo	731(389)	94.20(52.3)	775(413)	50.4(27.99)
Water Jacket Inlet	157(69)	1.99(1.1)	156(69)	1.24(0.69)
Water Jacket Outlet	170(76)	1.95(1.1)	170(76)	1.20(0.67)
Oil Sump	224(106)	1.76(1.0)	218(103)	1.59(0.88)
Fuel at Filter	95(35)	2.50(1.4)	92(33)	2.06(1.15)
Inlet Air	94(35)	5.30(2.9)	92(34)	4.33(2.41)
Airbox	263(128)	4.55(2.5)	221(105)	3.42(1.90)
Pressures				
Exhaust before Turbo, psi(kPa)	11.90(81.93)	0.76(5.27)	7.76(53.50)	0.28(1.93)
Exhaust after Turbo, in. Hg(kPa)	2.95(9.94)	0.17(0.57)	1.88(6.35)	0.08(0.25)
Compressor Discharge, psi(kPa)	12.23(84.30)	0.50(3.43)	8.69(59.95)	0.21(1.45)
Blower Discharge, psi(kPa)	17.68(121.93)	0.69(4.73)	10.53(72.58)	0.24(1.62)
Oil Gallery, psi (kPa)	54.11(373.09)	0.70(4.85)	47.25(325.76)	0.93(6.42)
Intake Vacuum, in. H_2O(kPa)	8.30(2.07)	0.33(0.08)	5.03(1.25)	0.28(0.07)
Ambient Conditions				
Dry Bulb Temperature, °F(°C)	81.2(27.3)	5.64(3.13)	80.1(26.7)	5.07(2.82)
Wet Bulb Temperature, °F(°C)	75.7(24.3)	6.73(3.02)	74.5(23.6)	6.05(3.36)
Barometric Pressure, in. Hg(kPa) (Both modes of operation)	29.2(98.6)	0.26(0.88)	--	--

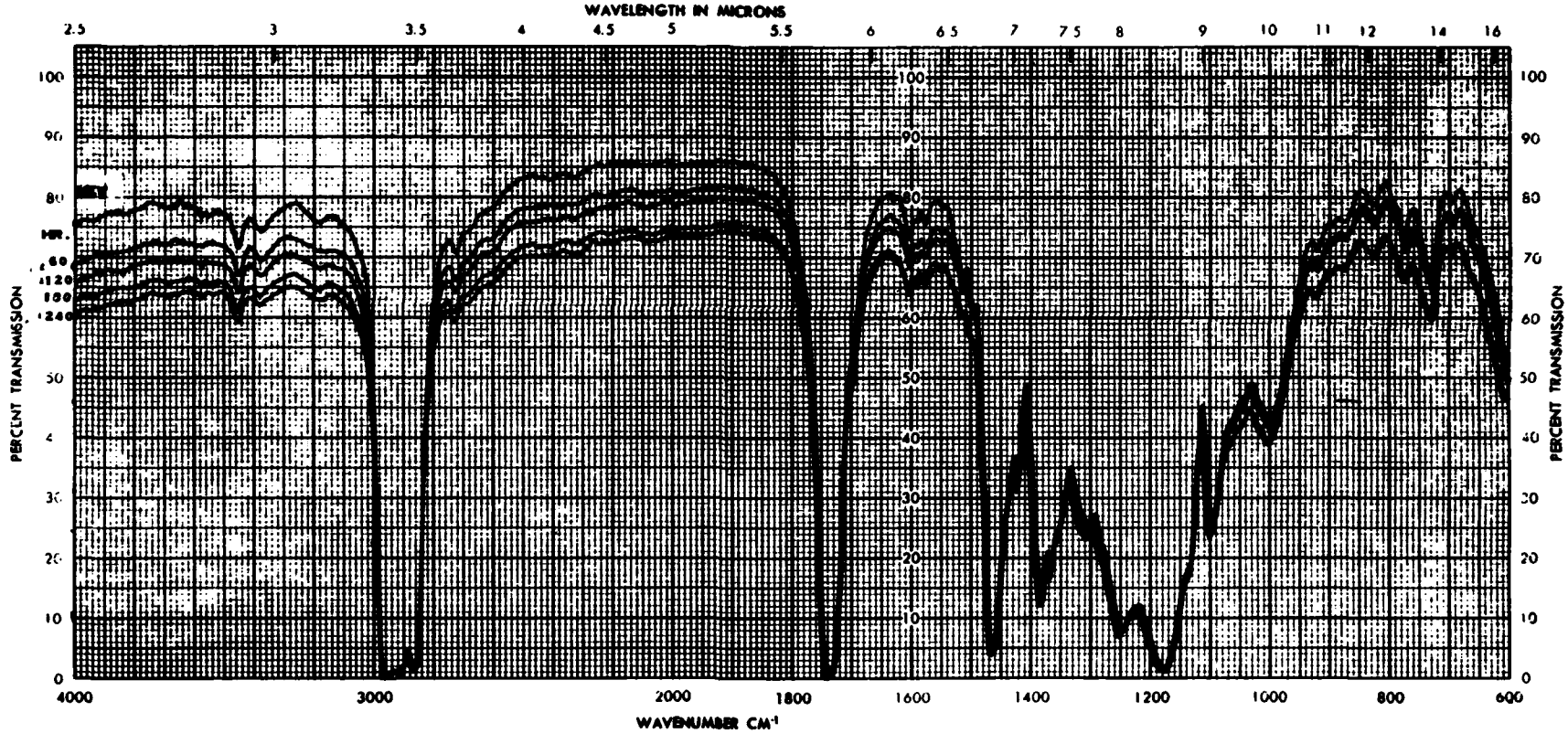
*68% of the values for a given variable occur within ±1 standard deviation of the mean; 95% occur within ±2 standard deviations.

6V-53T
TEST 31
LUBRICANT ANALYSIS
Lubricant: AL-12271-L

	ASTM Test Method	Test Time, Hours 0	20	40	60	80	100	120	140	160	180	200	220	240
Kinematic viscosity @ 40°C (104°F) cSt	D445	27.81	--	--	28.97	--	--	28.78	--	--	27.68	--	--	26.55
Kinematic viscosity @ 100°C (212°F) cSt	D445	6.19	6.95	6.47	6.32	6.33	6.39	6.42	6.17	6.24	6.13	6.11	5.96	6.08
Total Acid Number mg KOH/g	D664	0.20	--	--	0.31	--	--	0.23	--	--	0.23	--	--	0.23
Total Base Number mg KOH/g	D664	6.95	--	--	5.21	--	--	3.83	--	--	4.85	--	--	3.12
Pentane B Insolubles wtX	D893	0.01	--	--	0.04	--	--	0.18	--	--	0.11	--	--	0.21
Toluene B Insolubles wtX	D893	0.01	--	--	0.04	--	--	0.17	--	--	0.11	--	--	0.19
Flash Point, °C	D92	244	--	--	--	--	--	244	--	--	--	--	--	229

INFRARED SPECTRUM
6V-53T
TEST 31

Lubricant: AL-12271-L



6V-53T
TEST 31
Lubricant: AL-12271-L

TOTAL CONSUMPTION AND WEAR METALS BY XRF

Test Time, Hours	Total Oil Consumed, lb(kg)		Wear Metals, ppm Fe	Cu
0			11	<40
20	10.07	(4.57)	27	19
40	20.65	(9.37)	22	22
60	30.37	(13.78)	26	20
80	37.77	(17.13)	26	15
100	45.13	(20.47)	28	35
120	Oil change		26	<10
140	53.21	(24.13)	15	<10
160	60.60	(27.49)	14	<10
180	69.49	(31.52)	23	<10
200	76.60	(34.75)	23	<10
220	83.41	(37.83)	18	<10
240	94.62	(42.92)	20	<10

Average oil consumption rate: 0.39 lb/hr (0.18 kg/hr)

6V-53T
TEST 31
Lubricant: AL-12271-L

WEAR MEASUREMENTS*

Cylinder Liner Bore Diameter Change

	Cylinder Number 1L		2L		3L	
	T-AT**	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0006(0.015)	-0.0007(-0.018)	+0.0006(0.015)	-0.0006(-0.015)	+0.0003(0.008)	-0.0007(-0.018)
Middle	-0.0001(-0.003)	-0.0005(-0.013)	0.0000	-0.0003(-0.008)	-0.0002(-0.005)	-0.0002(-0.005)
Bottom	-0.0005(-0.013)	-0.0003(-0.008)	-0.0003(-0.008)	-0.0002(-0.005)	-0.0003(-0.008)	-0.0001(-0.003)

	Cylinder Number 1R		2R		3R	
	T-AT*	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0004(0.010)	-0.0004(-0.010)	+0.0004(0.010)	-0.0001(-0.003)	+0.0004(0.010)	-0.0003(-0.008)
Middle	0.0000	-0.0001(-0.003)	+0.0003(0.008)	-0.0001(-0.003)	+0.0001(0.003)	-0.0003(-0.008)
Bottom	-0.0003(-0.008)	0.0000	0.0000	-0.0003(0.008)	-0.0001(-0.003)	-0.0001(-0.003)

Average Change

	T-AT	F-B
Top	+0.0005(0.013)	-0.0005(-0.013)
Middle	0.0000	-0.0003(-0.008)
Bottom	-0.0003(-0.008)	-0.0002(-0.005)

Overall average change: -0.0001(-0.003)

Piston Ring End Gap Change

Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1	+0.002(0.05)	+0.004(0.10)	+0.002(0.05)	+0.002(0.05)	+0.008(0.20)	+0.002(0.05)	+0.003(0.08)
2	0.000	+0.002(0.05)	+0.001(0.03)	+0.004(0.10)	+0.002(0.05)	+0.002(0.05)	+0.002(0.05)
3	+0.001(0.03)	+0.001(0.03)	+0.001(0.03)	+0.002(0.05)	+0.002(0.05)	+0.003(0.08)	+0.002(0.05)
4	0.000	+0.001(0.03)	+0.002(0.05)	+0.002(0.05)	+0.003(0.08)	+0.002(0.05)	+0.002(0.05)
5	+0.007(0.18)	+0.007(0.18)	+0.007(0.18)	+0.007(0.18)	+0.006(0.15)	+0.007(0.18)	+0.007(0.18)
6	+0.009(0.23)	+0.006(0.15)	+0.006(0.15)	+0.006(0.15)	+0.005(0.13)	+0.006(0.15)	+0.006(0.15)
7	+0.008(0.13)	+0.006(0.15)	+0.006(0.15)	+0.004(0.10)	+0.004(0.10)	+0.007(0.18)	+0.006(0.15)

Overall average change: +0.004(0.10)

*All dimensions are given in inches (mm).
**T-AT = Thrust-Antithrust Direction; F-B = Front-Back Direction.

6V-53T
TEST 31
Lubricant: AL-12271-L
POST TEST ENGINE CONDITION AND DEPOSITS

A. Cylinder Liner

	1L	2L	3L	1R	2R	3R	Average
Intake Port Plugging, % restriction	<1	<1	<1	<1	<1	<1	<1
Liner Scuffing, % Area							
Thrust	0	3	2	1	7	4	2.83
Anti-Thrust	2	6	4	9	2	2	4.17
% Total Area Scuffing	1	4.5	3	5	4.5	3	3.50
						OVERALL:	3.50
% Area Bore Polished							
Thrust	3	1	1	3	2	2	2.00
Anti-Thrust	5	1	2	1	1	3	2.17
% Avg. Area Bore Polished	4	1	1.5	2	1.5	2.5	2.08
						OVERALL:	2.08

B. Pistons

Ring Face Distress, (demerits)							
No. 1	10.50	15.25	4.50	5.50	12.00	5.00	8.79
No. 2	0.25	1.25	0.75	0.00	8.75	0.50	1.92
No. 3	0.50	0.50	3.25	0.50	21.25	0.00	4.33
No. 4	0.25	0.50	1.25	0.00	18.75	0.25	3.50
						OVERALL:	3.13
Piston Skirt Rating							
Thrust	LS*	5%SC	S	S	S	S	
Anti-Thrust	S	LS	S	5%SC	S	S	
Piston WTD Rating**	266.38	298.50	279.50	259.00	278.63	279.00	276.84
Ring Sticking							
No. 1	F	F	F	F	F	F	
No. 2	F,C***	F	F,C	F	F	F	
No. 3	F	F	F	F	F	F	
No. 4	F	F	F	F	F	F	

C. Exhaust Valves

Deposits						
Head	← AHC+ →					
Face	← ½AHC →					
Tulip	← ½AHC →					
Stem	← #9 Lacquer++ →					
Surface Condition						
Freeness in Guide	F	F	F	F	F	F
Head	← Normal →					
Face	← Normal →					
Seat	← Normal →					
Stem	← Normal →					
Tip	← Normal →					

D. Other Ratings

Upper Oil Control Ring Expansion Force, lbs.	22.8	22.4	22.2	22.0	21.0	21.0	21.9

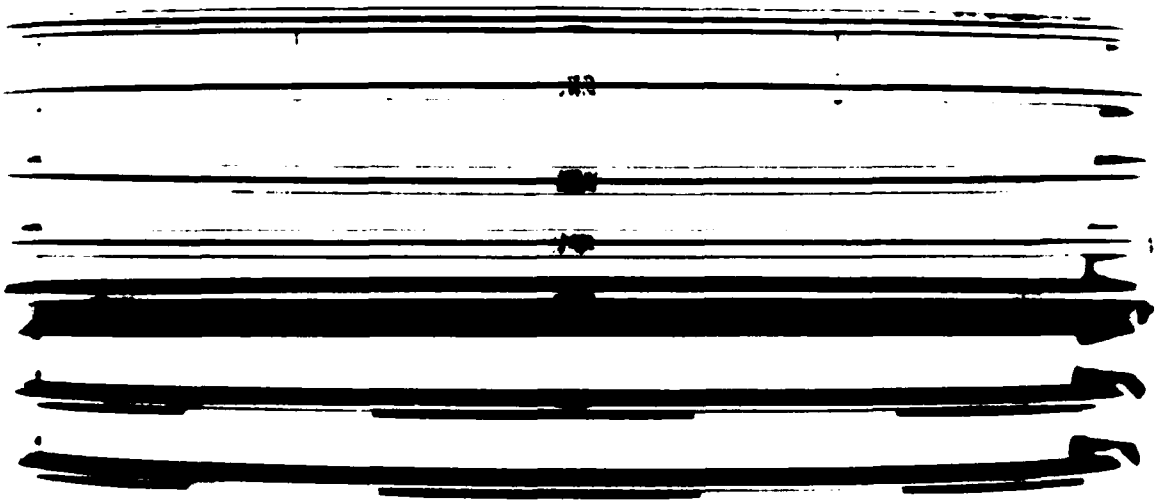
Bearing Surface Condition

Main Bearings	#2 Main Bearing has deep grooves cut down to copper
Rod Bearings	R-1 Connecting Rod Bearing worn through to copper front and rear with no wear in middle
Oil Pan	80% ½A sludge+++

*L = Light, S = Scratches, PM = Plating Melted, N = Normal, SC = Scuffing, B = Burn
**CRC Weighted Total Deposits (0 = least, 900 = most)
***HS = Hotstuck, CS Cold Stuck, P = Pinched, F = Free, N = Normal, C = Chipped
+HC = Hard Carbon; the number-letter, prefix indicates carbon depth with ½A = least to J = most
++ The higher the number, the darker the lacquer (0 = lightest, 9 = darkest)
+++Sludge depth ratings range from A to J. ½A equals an average depth which is approximately one half of the "A" depth as illustrated in CRC Manual No. 10.

6V53T(#31)
1-L

6V53T(#31)
1-R



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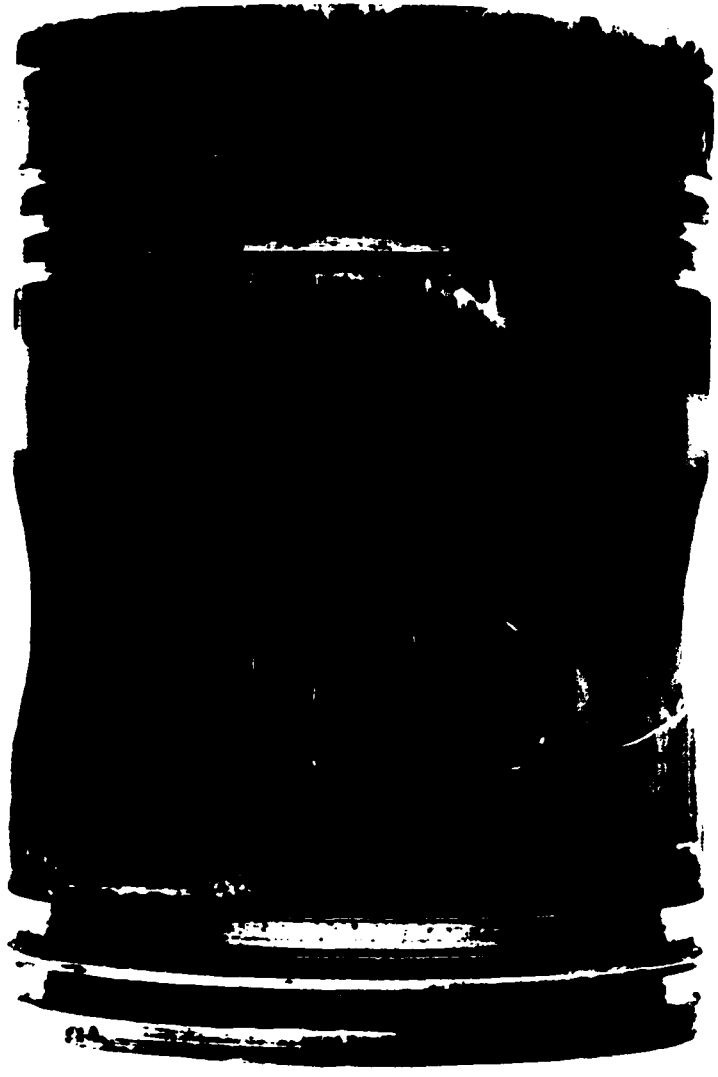
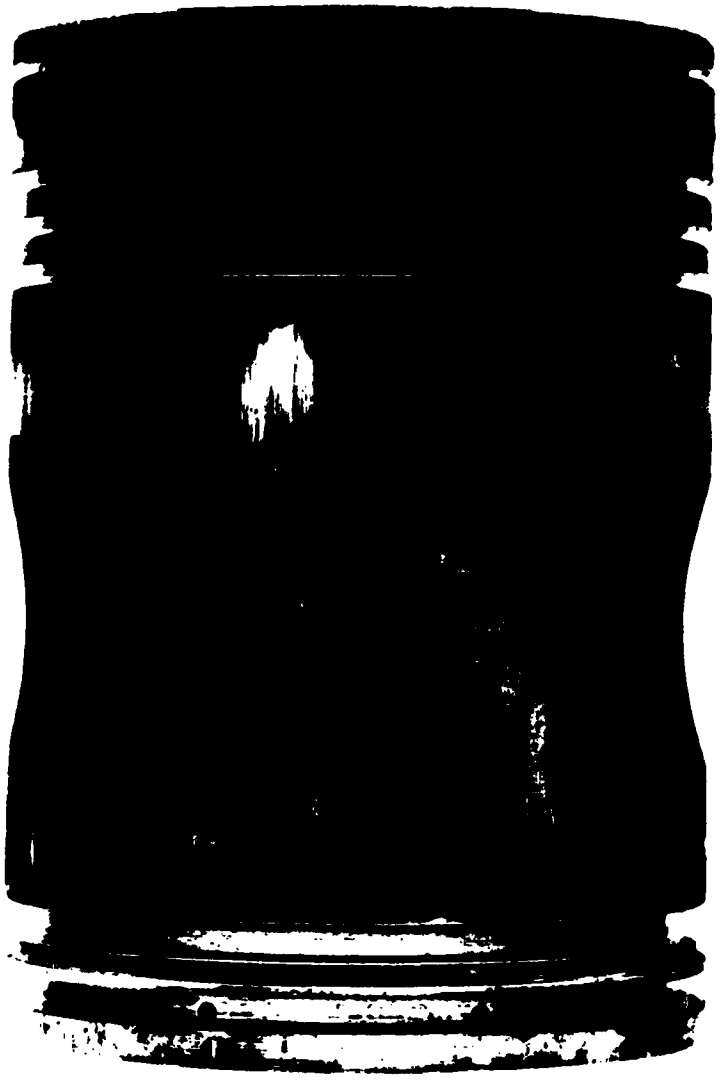
1-L-T

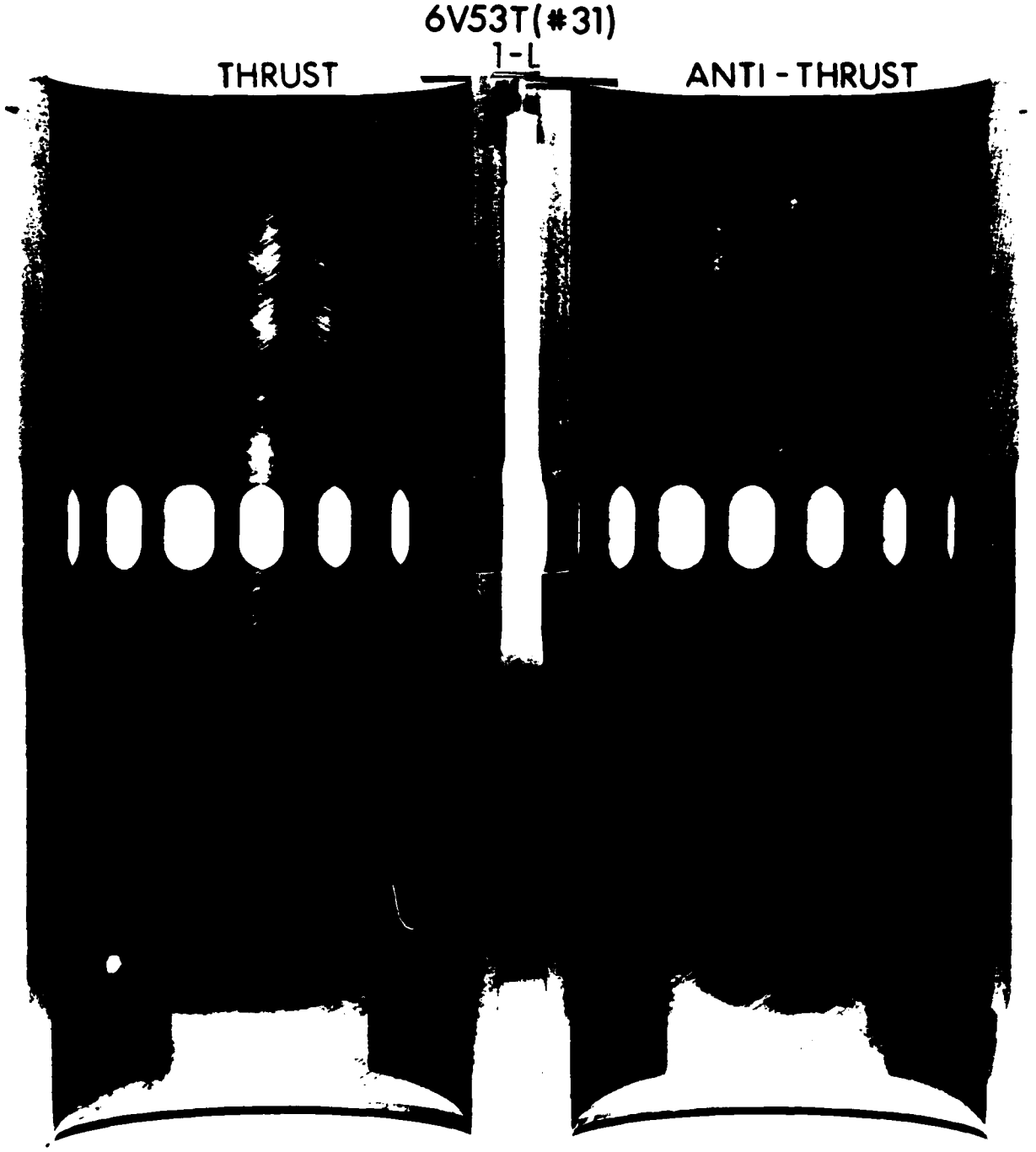


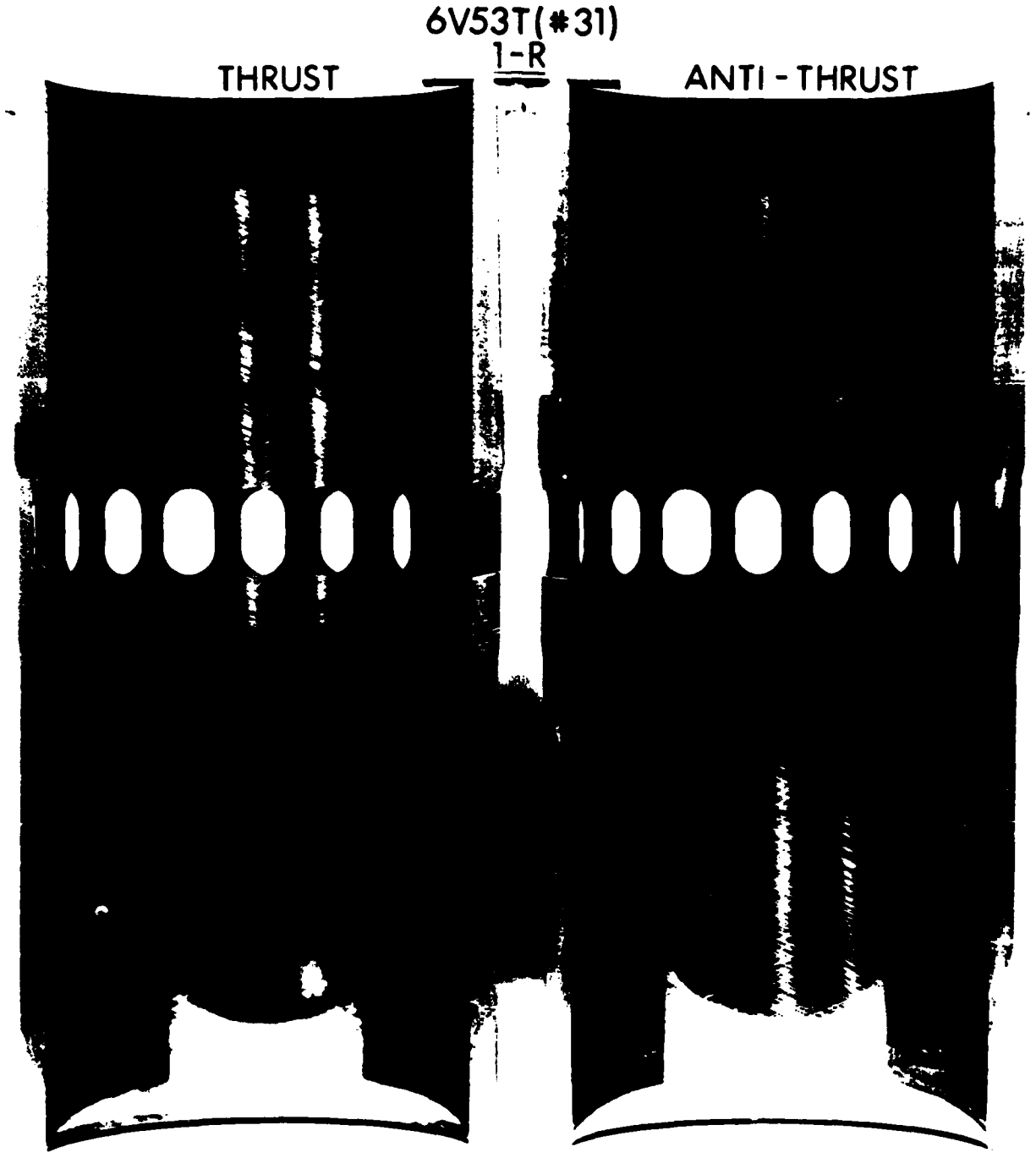
6V53T(#31)
1-L-AT

6V53T(#31)
1-R-T

6V53T(#31)
1-R-AT

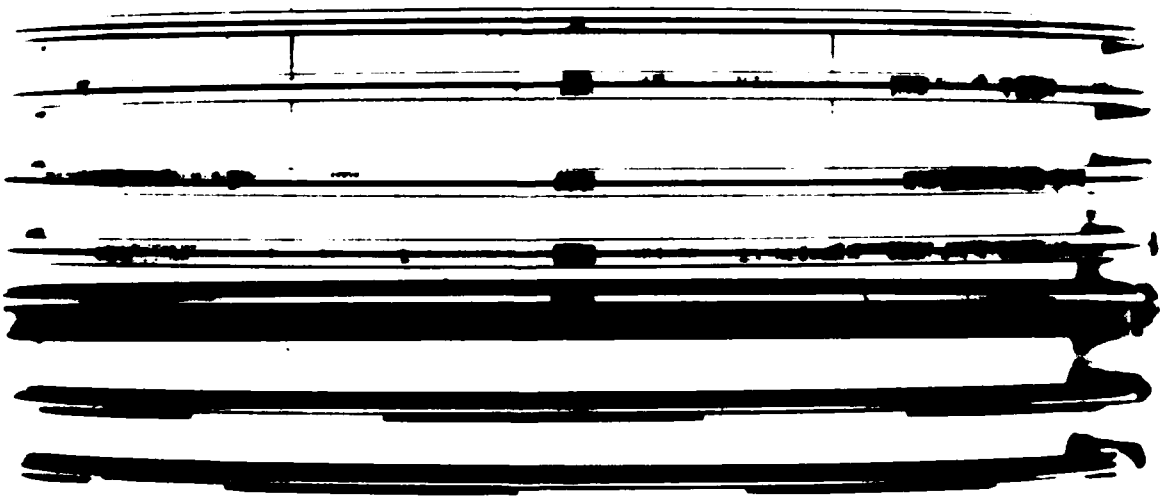



6V53T(#31)
1-L
THRUST
ANTI - THRUST


6V53T(#31)
1-R
THRUST
ANTI - THRUST

6V53T(#31)
2-L

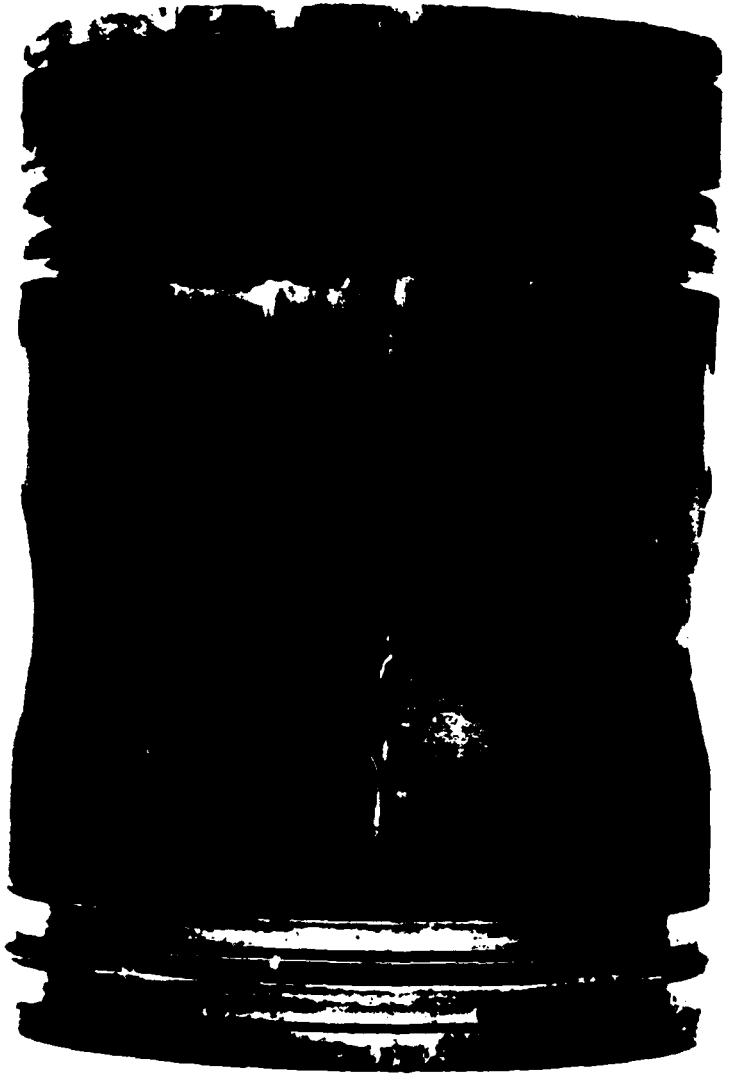
6V53T(#31)
2-R



6V53T(#31)
2-L-T

6V53T(#31)
2-L-AT

6V53T(#31)
2-R-T



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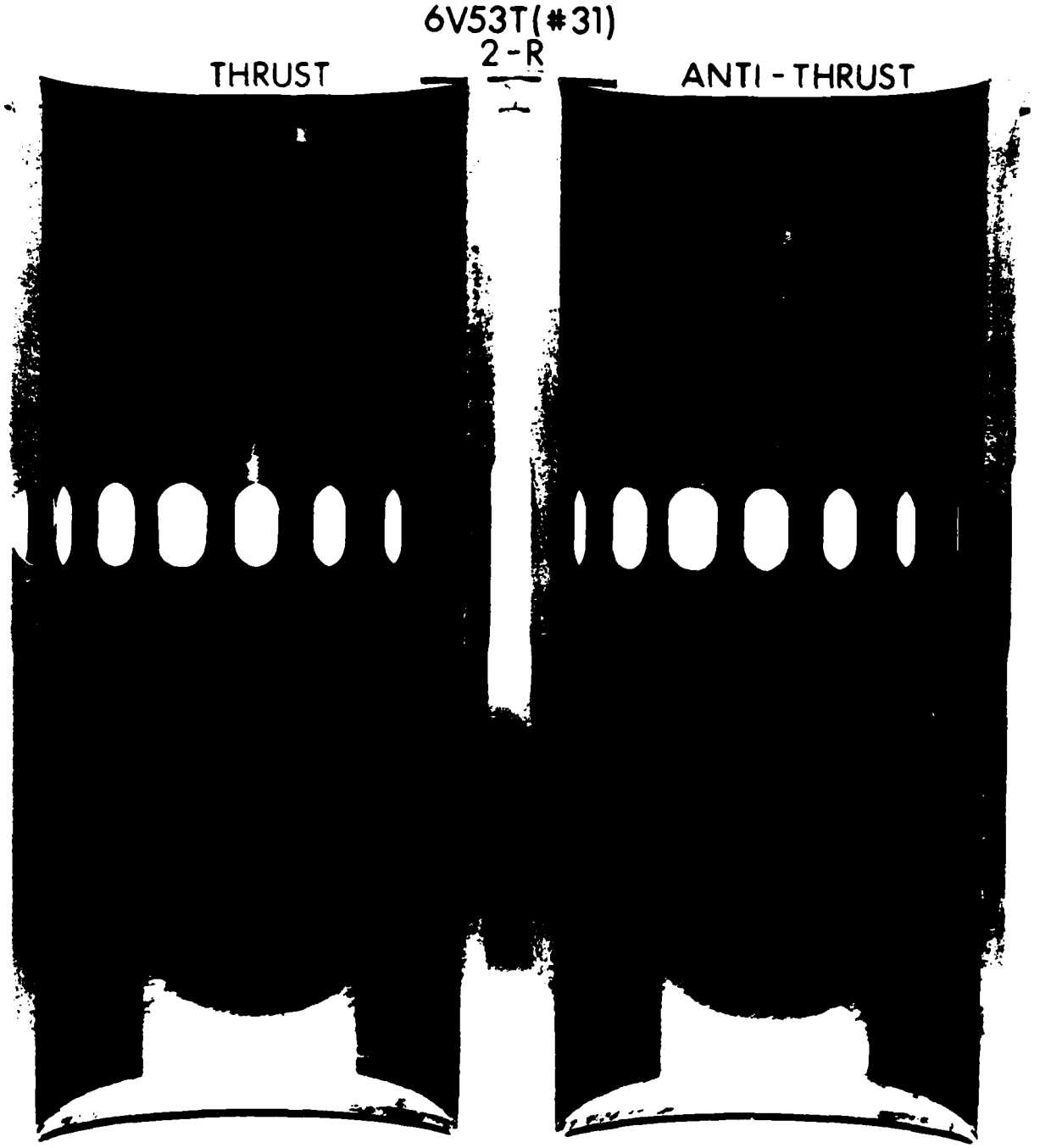
2-R-AT


6V53T(#31)
2-L
THRUST
ANTI-THRUST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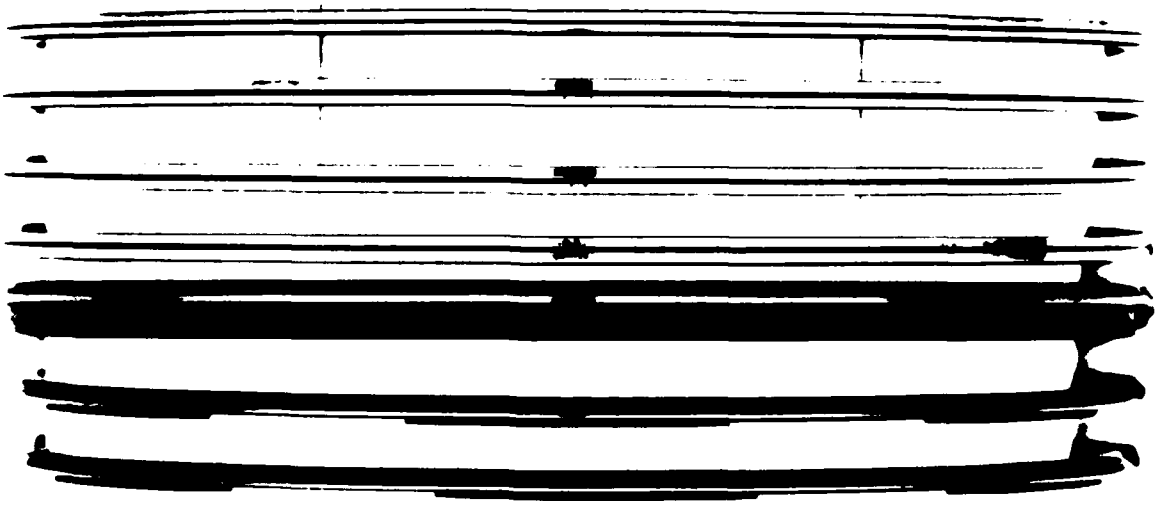
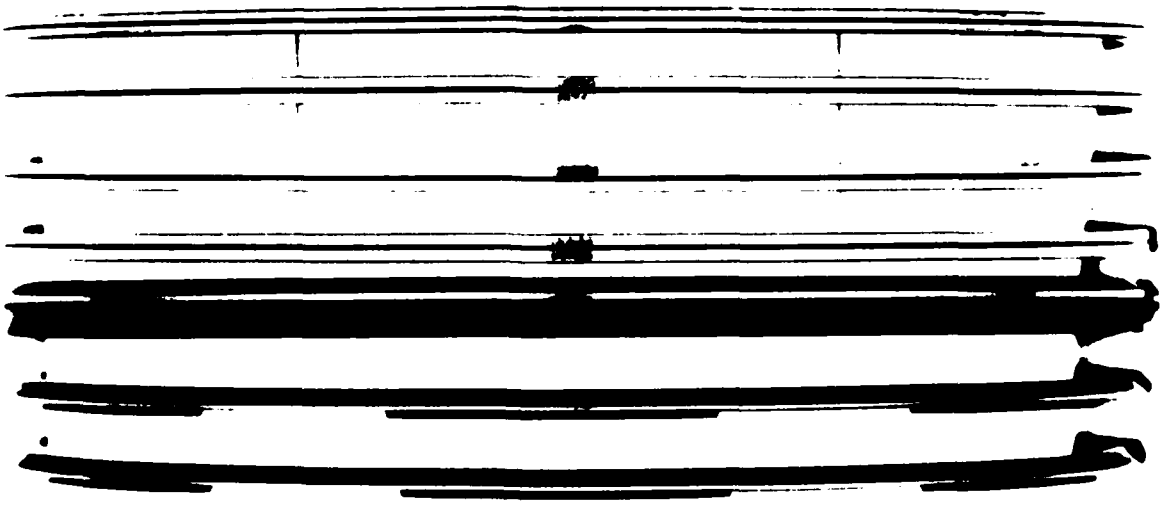
2-R
THRUST
ANTI - THRUST

6V53T(#31)
3-L

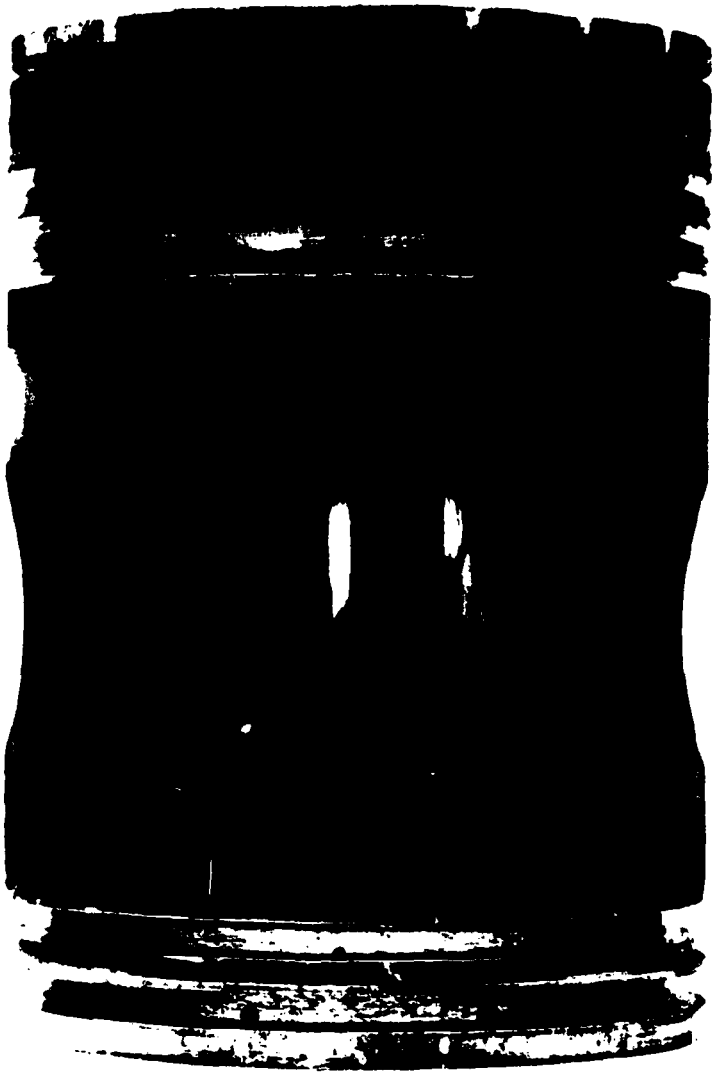


6V53T(#31)
3-R



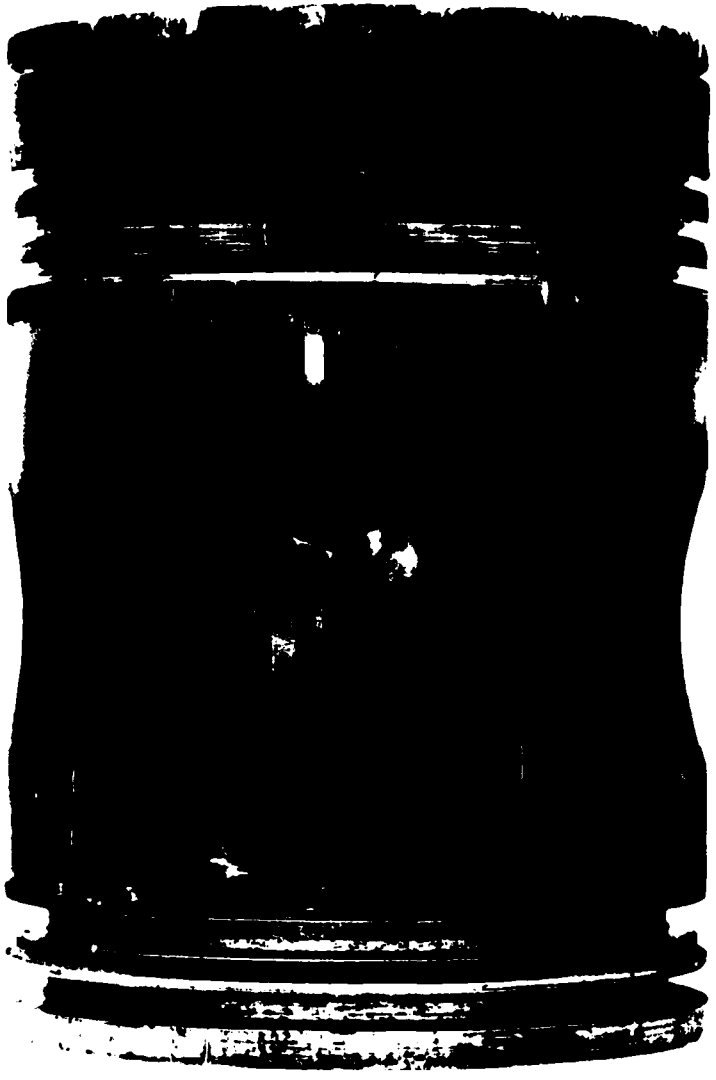
6V53T(#31)
3-L-T

6V53T(#31)
3-L-AT



6V53T(#31)
3-R-T

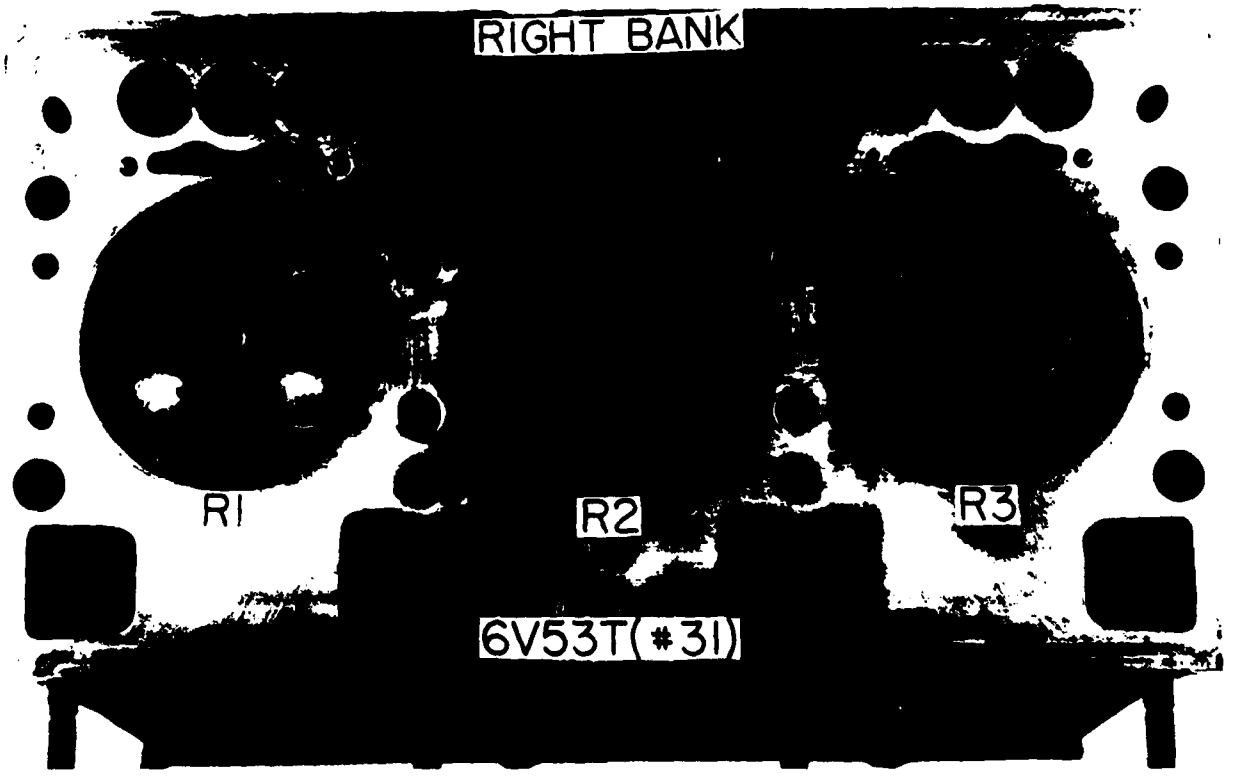
6V53T(#31)
3-R-AT




6V53T(#31)
3-L
THRUST
ANTI - THRUST


6V53T(#31)
3-R
THRUST
ANTI - THRUST


LEFT BANK
L3
L2
L1
6V53T(#31)


RIGHT BANK
R1
R2
R3
6V53T(#31)

APPENDIX C

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL FUEL

Lubricant AL-12271-L, Test No. 32

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL ENGINE

Test Lubricant: AL-12272-L
Test Fuel: Caterpillar 1-H
Engine Test Number: 32*
Date Completed: 20 July 1983

Conducted For

U.S. Army Mobility Equipment Research and Development Command
Materials, Fuels and Lubricants
Fort Belvoir, Virginia

by

U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

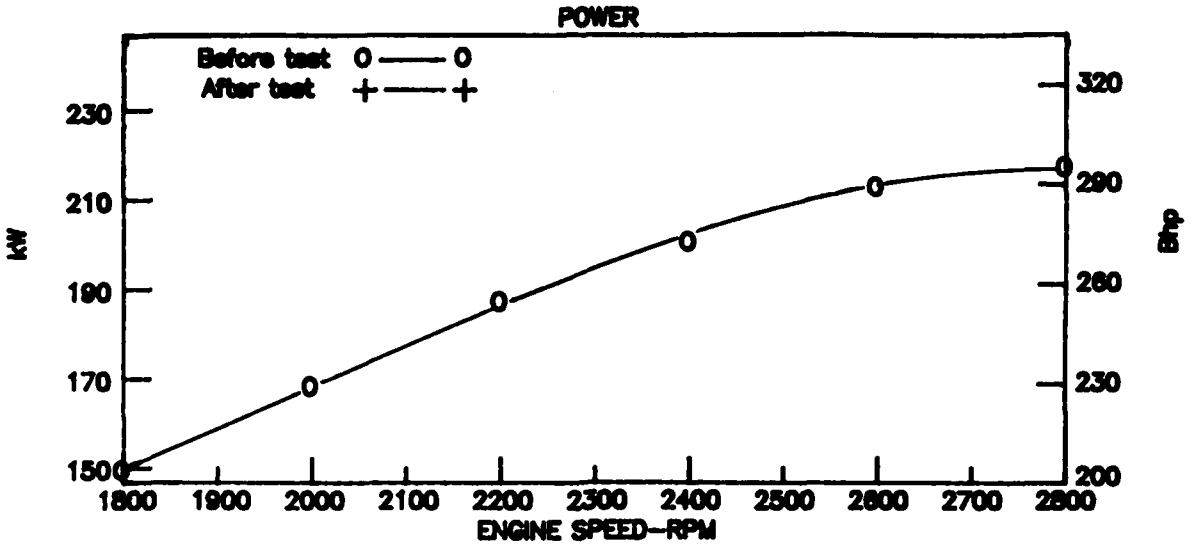
*Test stopped at 60 hours due to severe scuffing and #2 main bearing failure.

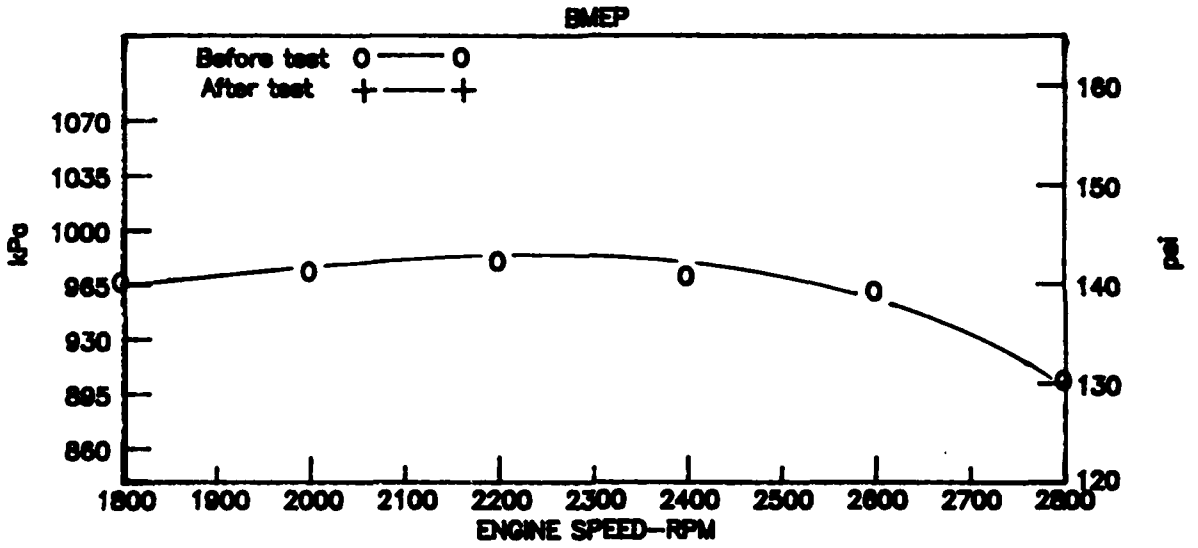
6V-53T
TEST 32
ENGINE REBUILD MEASUREMENTS*
Model Number: 5063-5395
Serial Number: 6D-157211

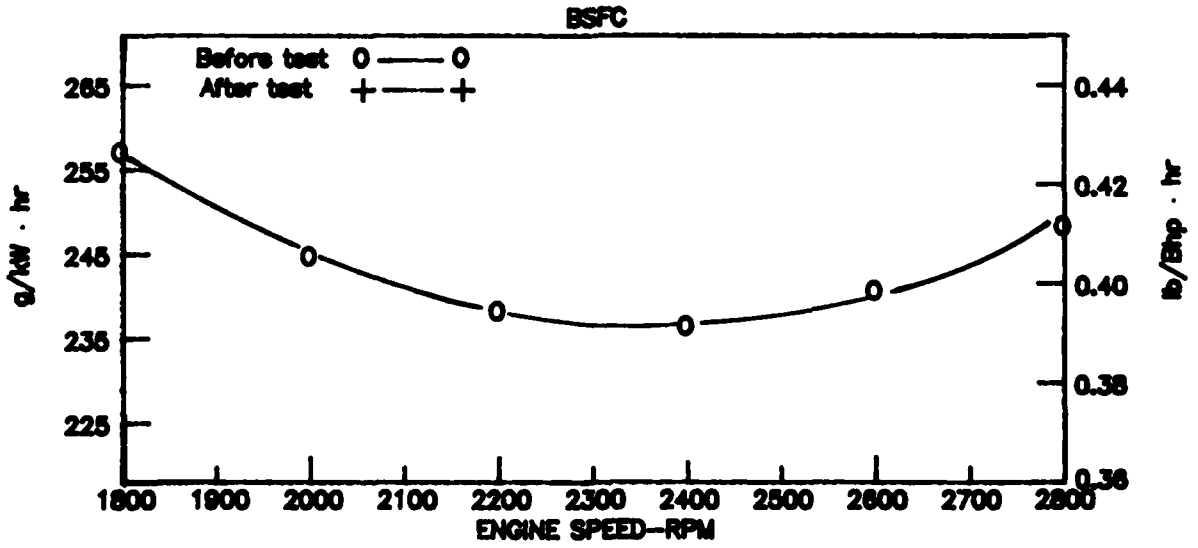
	Min	Max	Avg	Specified Limits	
Cylinder Block Bore					
Inside Diameter (Bottom)	4.3565(110.655)	4.3582(110.698)	4.3573(110.675)	4.3565(110.655)	- 4.3575(110.681) New - 4.3595(110.731) Max
Out-of-Round	0.0000	0.0012(0.030)	0.0004(0.010)		- 0.0015 (0.038) Max
Taper	0.0000	0.0012(0.030)	0.0004(0.010)		- 0.0015 (0.038) Max
Cylinder Liners (Installed)					
Inside Diameter	3.8756(98.440)	3.8766(98.466)	3.8761(98.453)	3.8752(98.430)	- 3.8767(98.468)
Out-of-Round	0.0000	0.0005(0.013)	0.0002(0.005)		- 0.0015(0.038) Max
Taper	0.0000	0.0007(0.018)	0.0002(0.005)		- 0.0015(0.038) Max
Piston Diameter (at skirt)	3.8680(98.247)	3.8690(98.273)	3.8685(98.260)	3.8669(98.219)	- 3.8691(98.775)
Piston Skirt to Cylinder Liner Clearance	0.0069(0.175)	0.0084(0.213)	0.0076(0.193)	0.0061(0.155)	- 0.0098(0.249)
Compression Rings					
Gap (No. 1, Fire Ring)	0.030(0.76)	0.036(0.91)	0.033(0.84)	0.020(0.51)	- 0.046(1.17)
Gap (Nos. 2, 3, 4)	0.030(0.76)	0.036(0.91)	0.032(0.81)	0.020(0.51)	- 0.036(0.91)
Ring-to-Groove Clearance					
Top (No. 1, Fire Ring)	0.003(0.08)	0.003(0.08)	0.003(0.08)	0.003(0.08)	- 0.006(0.15)
No. 2, Compression Ring	0.007(0.18)	0.008(0.20)	0.008(0.20)	0.007(0.18)	- 0.010(0.25)
No. 3 and 4, Compression Rings	0.006(0.15)	0.007(0.18)	0.006(0.15)	0.005(0.13)	- 0.008(0.20)
Oil Control Rings, Nos. 5, 6, 7					
Gap	0.017(0.43)	0.019(0.48)	0.018(0.46)	0.010(0.25)	- 0.025(0.64)
Ring-to-Groove Clearance	0.002(0.05)	0.003(0.08)	0.003(0.08)	0.0015(0.038)	- 0.0055(0.140)
Piston Pin					
Pin-to-Piston Bushing Clearance	0.0032(0.081)	0.0034(0.086)	0.0033(0.084)	0.0025(0.064)	- 0.0034(0.086)
Pin-to-Connecting Rod Bushing Clearance	0.0019(0.048)	0.0019(0.048)	0.0019(0.048)	0.0010(0.025)	- 0.0019(0.048)
Connecting Rod Bearing-to-Journal Clearance	0.0018(0.046)	0.0036(0.091)	0.0028(0.071)	0.0011(0.028)	- 0.0041(0.104)
Main Bearing-to-Journal Clearance	0.0039(0.099)	0.0040(0.102)	0.0039(0.099)	0.0010(0.025)	- 0.0040(0.102)
Camshaft Bearing-to-Journal Clearance	0.0055(0.140)	0.0059(0.150)	0.0057(0.145)	0.0045(0.114)	- 0.0060(0.152)

*Measurements are in inches and (mm)

6V-53T 240-HOUR TRACKED VEHICLE CYCLE
BEFORE TEST 32 PERFORMANCE DATA







6V-53T
240-HOUR TRACKED VEHICLE CYCLE ENDURANCE TEST
TEST 32
OPERATING CONDITIONS SUMMARY

Lubricant: AL-12272-L Fuel: Caterpillar 1-H

	Maximum Power Mode (2800 RPM)		Maximum Torque Mode (2200 RPM)	
	Mean	Standard Deviation	Mean	Standard Deviation
Engine Speed, rpm	2800	3.11	2200	4.49
Torque, ft-lb (N-m)	516(700)	4.00(5.41)	580(786)	2.71(3.67)
Fuel Consumption, lb/hr(kg/hr)	111(50.4)	0.67(0.30)	94(42.4)	0.66(0.30)
Observed Power, Bhp(kW)	275(205)	2.12(1.58)	242(181)	1.25(0.94)
BSFC, lb/Bhp-hr(g/kW-hr)	0.405(246)	0.003(1.82)	0.386(234)	0.003(1.67)
Temperatures, °F(°C)				
Exhaust before Turbo	887(475)	25.00(13.9)	877(470)	23.90(13.3)
Exhaust after Turbo	739(393)	17.50(9.75)	767(409)	21.80(12.1)
Water Jacket Inlet	157(69.6)	1.12(0.62)	155(68.6)	1.41(0.78)
Water Jacket Outlet	170(76.9)	1.29(0.71)	169(76.0)	1.60(0.89)
Oil Sump	229(110)	1.63(0.91)	221(105)	2.09(1.16)
Fuel at Filter	92(33.4)	1.15(0.64)	90(32)	1.04(0.58)
Inlet Air	93(34.0)	2.89(1.61)	91(32.8)	1.94(1.08)
Airbox	252(122)	3.83(2.13)	209(98.4)	2.09(1.16)
Pressures				
Exhaust before Turbo, psi(kPa)	12.3(84.9)	0.17(1.17)	8.1(55.7)	0.14(0.98)
Exhaust after Turbo, in. Hg(kPa)	3.1(10.6)	0.22(0.73)	1.9(6.32)	0.22(0.74)
Compressor Discharge, psi(kPa)	12.9(89.0)	0.37(2.56)	9.0(61.7)	0.30(2.06)
Blower Discharge, psi(kPa)	19.2(132.0)	0.45(3.10)	11.4(78.9)	0.46(3.20)
Oil Gallery, psi (kPa)	49.8(344.0)	1.70(11.70)	43.6(300.0)	1.15(7.90)
Intake Vacuum, in. H_2O(kPa)	8.6(2.14)	0.33(0.08)	5.0(1.24)	0.29(0.07)
Ambient Conditions				
Dry Bulb Temperature, °F(°C)	79.42(26.3)	3.79(2.11)	77.70(25.4)	2.03(1.13)
Wet Bulb Temperature, °F(°C)	74.76(23.8)	2.34(1.30)	74.40(23.5)	2.43(1.35)
Barometric Pressure, in. Hg(kPa) (Both modes of operation)	29.16(98.5)	0.10(0.34)		

*68% of the values for a given variable occur within ±1 standard deviation of the mean; 95% occur within ±2 standard deviations.

6V-53T
TEST 32
LUBRICANT ANALYSIS
Lubricant: AL-12272-L

	ASTM Test Method	Test Time, Hours 0	20	40	60
Kinematic viscosity @ 40°C (104°F) cSt	D445	32	--	--	30.6
Kinematic viscosity @ 100°C (212°F) cSt	D445	6.37	5.95	5.92	5.89
Total Acid Number mg KOH/g	D664	2.10	--	--	2.41
Total Base Number mg KOH/g	D664	7.91	--	--	3.53
Pentane B Insolubles wt%	D893	0.0	--	--	0.06
Toluene B Insolubles wt%	D893	0.0	--	--	0.06
Flash Point, °C	D92	229	--	--	234

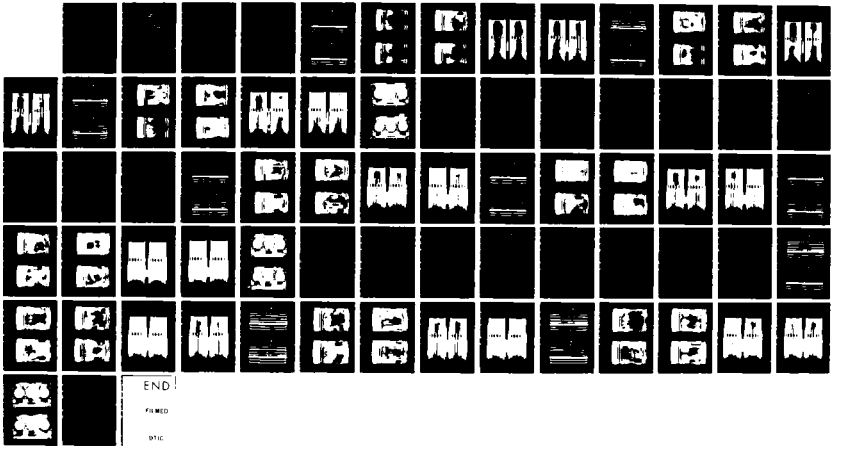
TOTAL CONSUMPTION AND WEAR METALS BY XRF

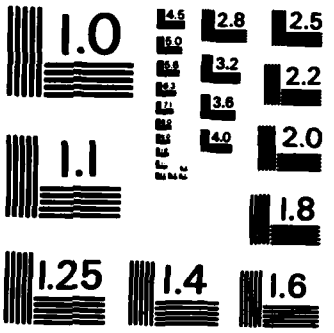
Test Time, Hours	Total Oil Consumed, lb(kg)		Wear Metals, ppm Fe	Cu
0			20	<10
20	6.16	(2.79)	76	<10
40	16.72	(7.58)	163	<10
60	26.16	(11.87)	205	22

Average oil consumption rate: 0.44 lb/hr (0.20 kg/hr)

AD-A146 465 CORRELATION OF FEDERAL TEST METHOD STANDARD 791B METHOD 354 WITH ARMY 240.. (U) SOUTHWEST RESEARCH INST SAN ANTONIO TX ARMY FUELS AND LUBRICA.. 2/2

UNCLASSIFIED A F MONTEMAYOR ET AL. 30 SEP 83 AFLRL-180 F/G 11/8 NL





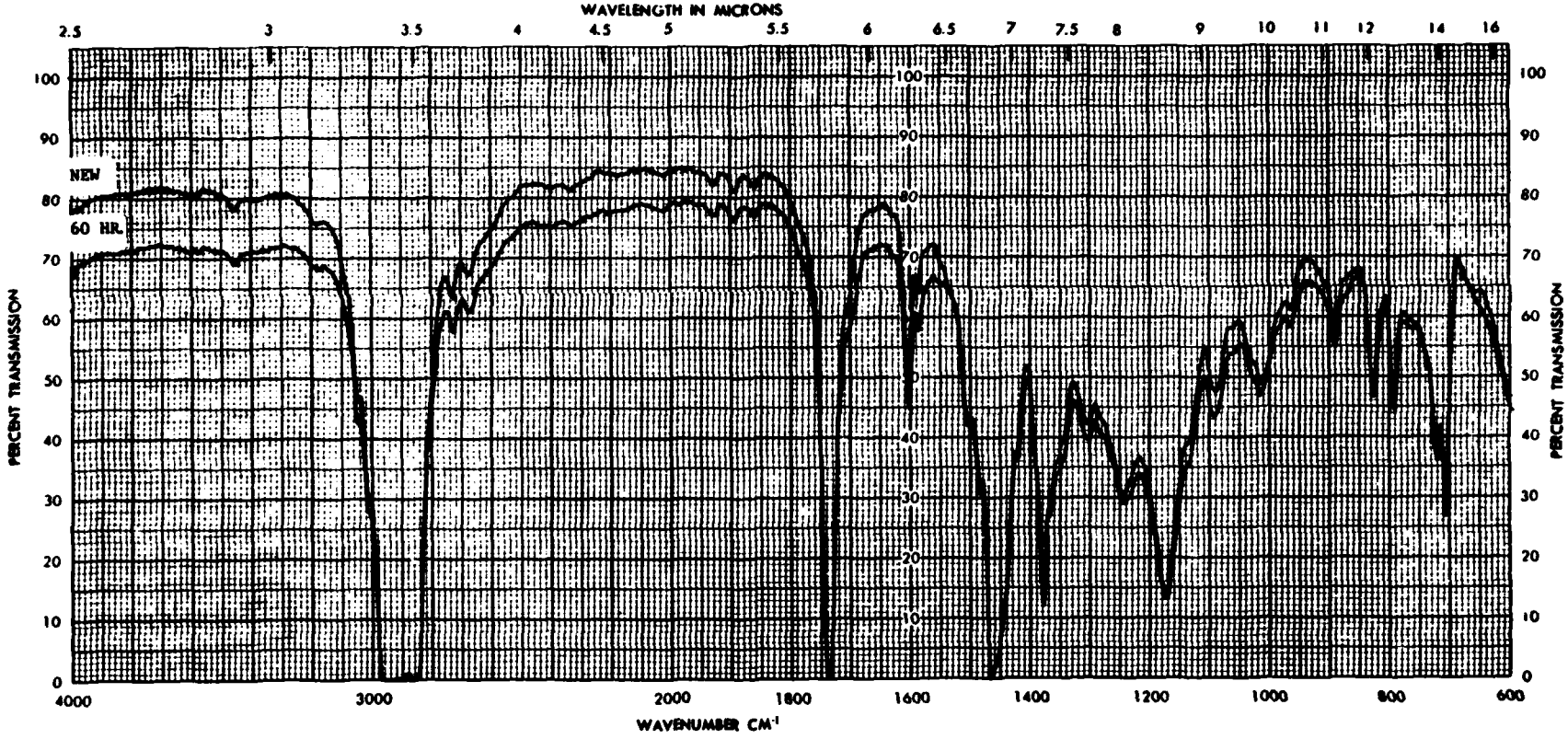
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963 - A

INFRARED SPECTRUM

6V-53T

TEST 32

Lubricant: AL-12272-L



6V-53T
TEST 32
Lubricant: AL-12272-L

WEAR MEASUREMENTS*

Cylinder Liner Bore Diameter Change

	Cylinder Number 1L		2L		3L	
	T-AT**	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0001(0.03)	-0.0005(-0.013)	-0.0001(-0.003)	-0.0005(-0.013)	+0.0006(0.015)	-0.005(-0.013)
Middle	0.0000	-0.0005(-0.013)	-0.0001(-0.003)	-0.0003(-0.008)	-0.0004(-0.010)	-0.0006(-0.015)
Bottom	-0.0003(-0.008)	-0.0005(-0.013)	-0.0004(-0.010)	-0.0005(-0.013)	-0.0004(-0.010)	-0.0005(-0.013)

	Cylinder Number 1R		2R		3R	
	T-AT*	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0001(0.003)	-0.0005(-0.013)	+0.0003(0.008)	-0.0003(-0.008)	Not Measured - Severe Scuffing***	
Middle	-0.0004(-0.10)	-0.0006(-0.015)	-0.0001(-0.003)	+0.0002(0.005)	Removed liner and STOPPED TEST	
Bottom	-0.0002(-0.005)	-0.0004(-0.010)	-0.0004(-0.010)	-0.0003(-0.008)	Removed liner and STOPPED TEST	

Average Change

	T-AT	F-B
Top	+0.0002(0.005)	-0.0005(-0.013)
Middle	-0.0002(-0.005)	-0.0004(-0.010)
Bottom	-0.0003(-0.008)	-0.0004(-0.010)

Overall average change: -0.0003(-0.008)

Piston Ring End Gap Change

Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1	+0.002(0.05)	+0.005(0.13)	+0.001(0.03)	0.000	+0.004(0.10)	+0.008(0.20)	+0.003(0.08)
2	0.000	0.000	+0.001(0.03)	0.000	-0.002(-0.05)	0.000	0.000
3	+0.002(0.05)	0.000	0.000	0.000	0.000	+0.001(0.03)	+0.001(0.03)
4	+0.001(0.03)	-0.002(-0.05)	+0.001(0.03)	0.000	0.000	+0.001(0.03)	0.000
5	+0.006(0.15)	+0.033(0.84)	+0.006(0.15)	+0.010(0.25)	+0.005(0.13)	+0.098(2.49)	+0.026(0.66)
6	+0.003(0.08)	+0.036(0.91)	+0.004(0.10)	+0.005(0.13)	+0.002(0.05)	+0.013(0.33)	+0.011(0.28)
7	+0.003(0.08)	+0.033(0.84)	+0.002(0.05)	+0.005(0.13)	+0.002(0.05)	+0.015(0.38)	+0.010(0.25)

Overall average change: +0.009(0.23)

*All dimensions are given in inches (mm).
**T-AT = Thrust-Antithrust Direction; F-B = Front-Back Direction.
***Not included in averages.

6V-53T
TEST 32
Lubricant: AL-12272-L

POST TEST ENGINE CONDITION AND DEPOSITS

A. Cylinder Liner

	1L	2L	3L	1R	2R	3R	Average
Intake Port Plugging, % restriction	<1	<1	<1	<1	<1	<1	<1
Liner Scuffing, % Area							
Thrust	3	41	4	4	3	100	25.83
Anti-Thrust	1	88	17	1	12	100	36.50
% Total Area Scuffing	2	64.5	10.5	2.5	7.5	100	31.17
						OVERALL:	31.17
% Area Bore Polished							
Thrust	1	0	0	0	1	0	0.33
Anti-Thrust	1	0	0	2	2	0	0.83
% Avg. Area Bore Polished	1	0	0	1	1.5	0	0.58
						OVERALL:	0.58

B. Pistons

Ring Face Distress, (demerits)							
No. 1	24.00	43.25	22.75	15.75	4.00	72.50	30.38
No. 2	1.25	63.75	12.50	0.00	27.75	35.00	23.38
No. 3	2.75	58.75	27.50	0.00	27.50	36.25	25.46
No. 4	2.00	65.00	21.25	0.00	33.75	33.75	25.96
						OVERALL:	24.42
Piston Skirt Rating							
Thrust	S*	70%SC	S	S	S	35%SC	
Anti-Thrust	S	45%SC	20%SC	S	S	15%SC	
Piston WTD Rating**	229.88	168.38	197.50	163.88	223.25	231.88	202.46
Ring Sticking							
No. 1	F***	CF	F	F	F	CF	
No. 2	F	F	F	F	F	F	
No. 3	F	F	F	F	F	F	
No. 4	F	F	F	F	F	F	

C. Exhaust Valves

Deposits						
Head	½ to ½ AHC+					
Face	½AHC					
Tulip	½AHC					
Stem	#9 Lacquer++					
Surface Condition						
Freeness in Guide	F	F	F	F	F	F
Head	Normal					
Face	Normal					
Seat	Normal					
Stem	Normal					
Tip	Normal					

D. Other Ratings

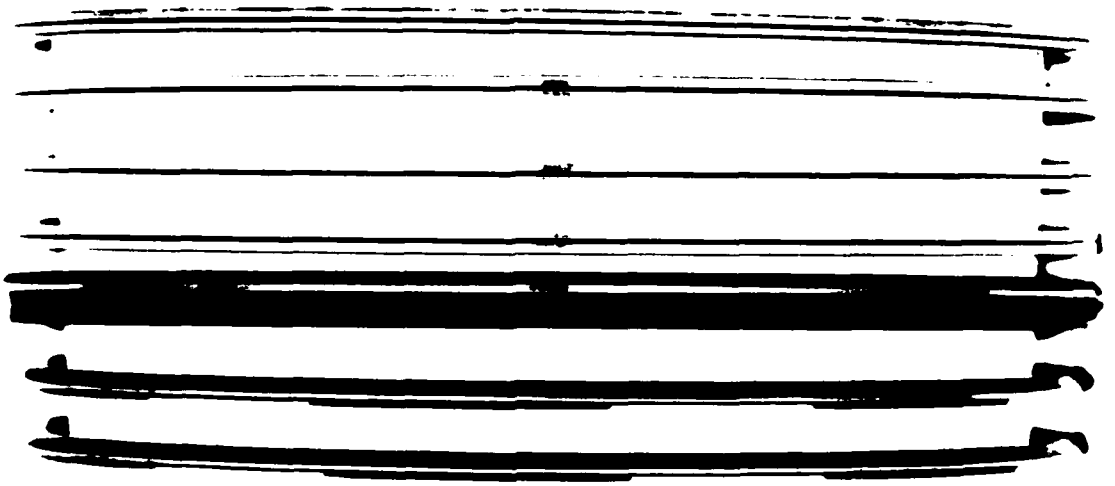
Upper Oil Control Ring Expansive Force, lbs.	19.2	19.8	20.0	20.0	19.2	20.0	19.7

Bearing Surface Condition

Main Bearings	#2 babbit flaking off and almost to point of melting; remaining bearings had scratches with #4 showing copper.
Rod Bearings	1R worn to copper; remaining bearings have scratches and some copper imbedded in them.
Cam Bearings	Have a few scratches.

*L = Light, S = Scratches, PM = Plating Melted, N = Normal, SC = Scuffing, B = Burn
**CRC Weighted Total Deposits (0 = least, 900 = most)
***HS = Hotstuck, CS Cold Stuck, P = Pinched, F = Free, N = Normal, C = Chipped
+HC = Hard Carbon; the number-letter, prefix indicates carbon depth with ½A = least to J = most
++= The higher the number, the darker the lacquer (0 = lightest, 9 = darkest)

6V53T(#32)
1-L



6V53T(#32)
1-R

6V53T(#32)
1-L-T

6V53T(#32)
1-L-AT

6V53T(#32)
1-R-T

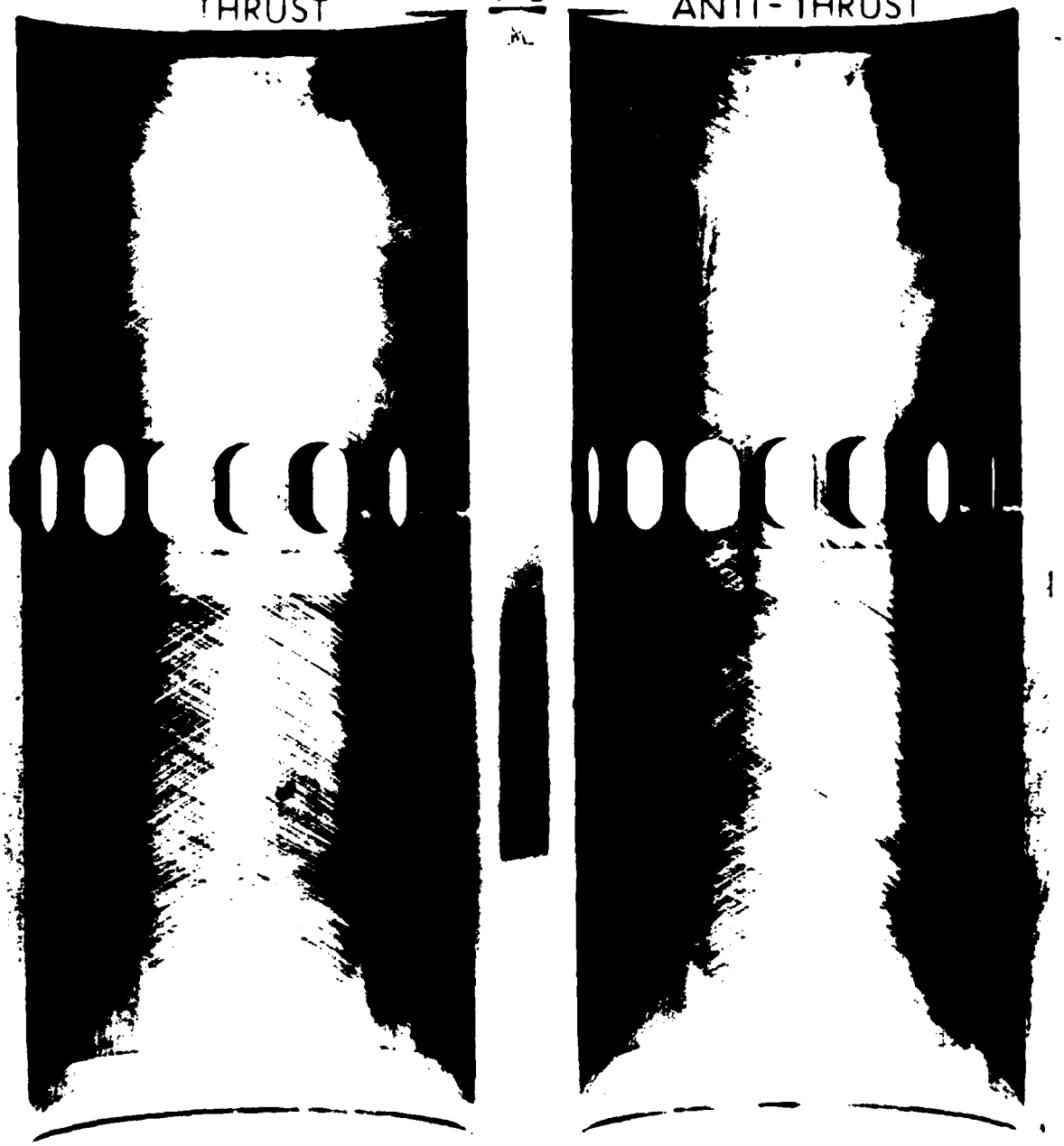
6V53T(#32)
1-R-AT

6V53T(#32)

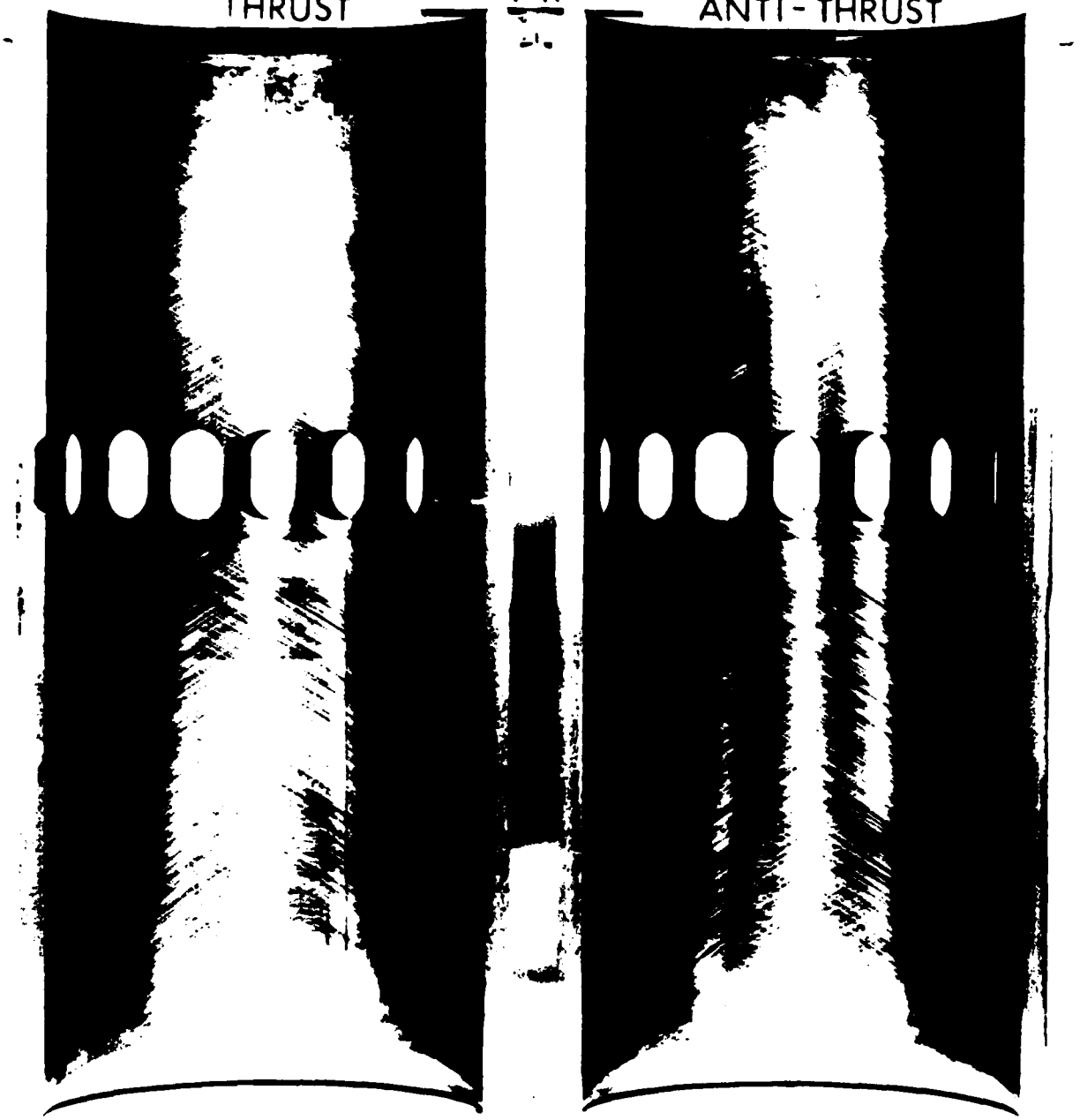
1-L

THRUST

ANTI-THRUST



6V53T(#32)
1-R



6V53T(#32)
2-L

6V53T(#32)
2-R

6V53T(#32)
2-L-T

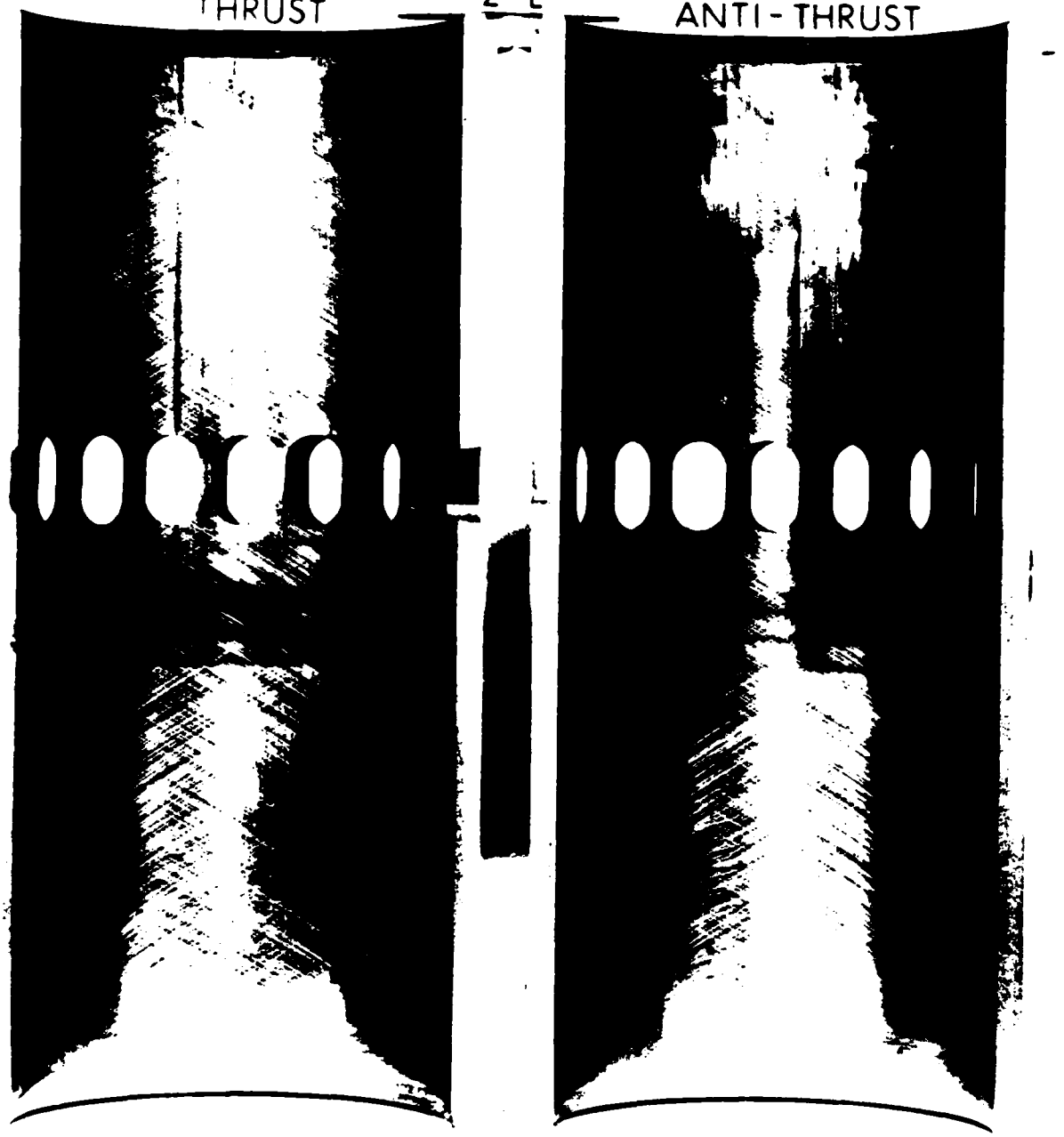
6V53T(#32)
2-L-AT

6V53T(#32)
2-R-T

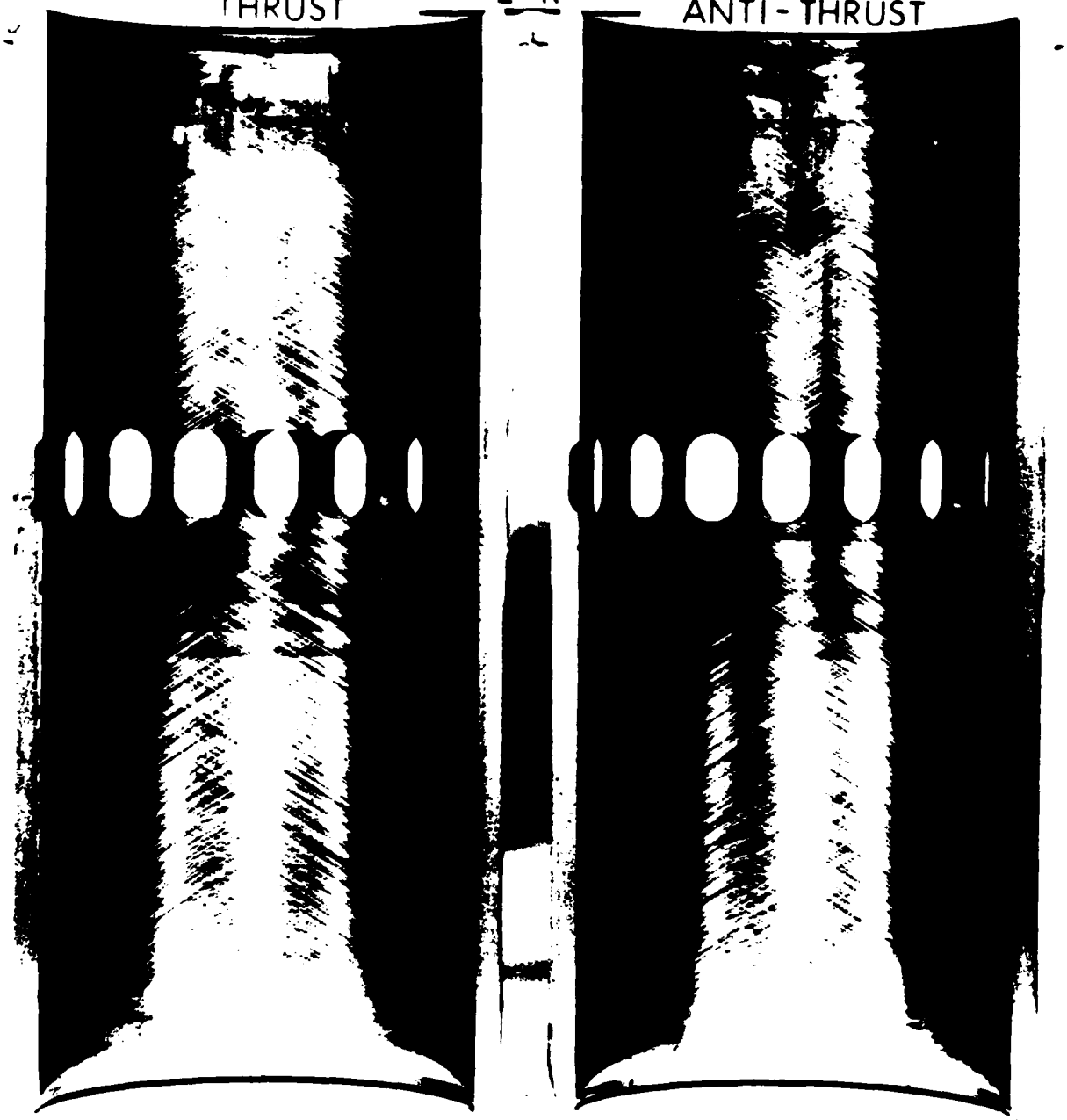
6V53T(#32)
2-R-AT

6V53T(#32)

2-L

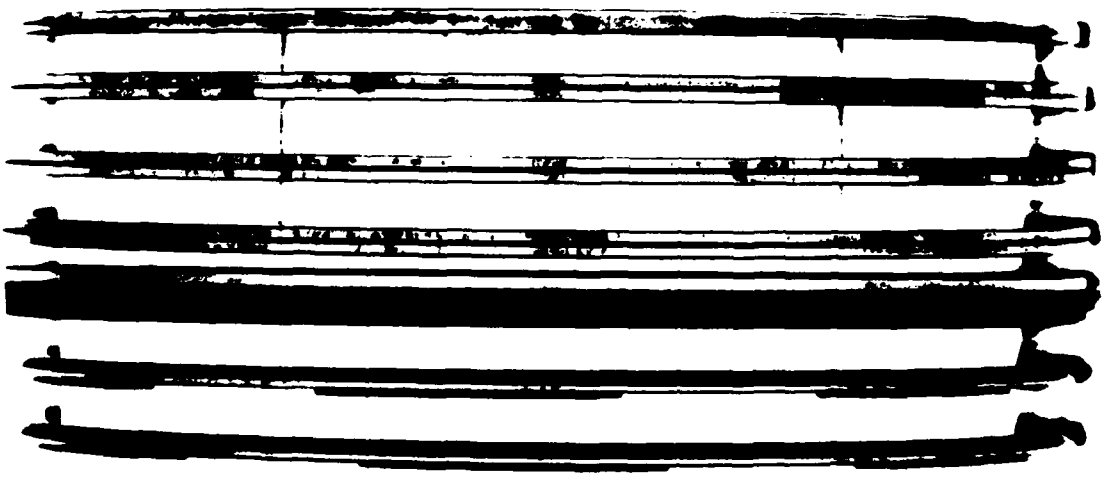


6V53T(#32)
2-R

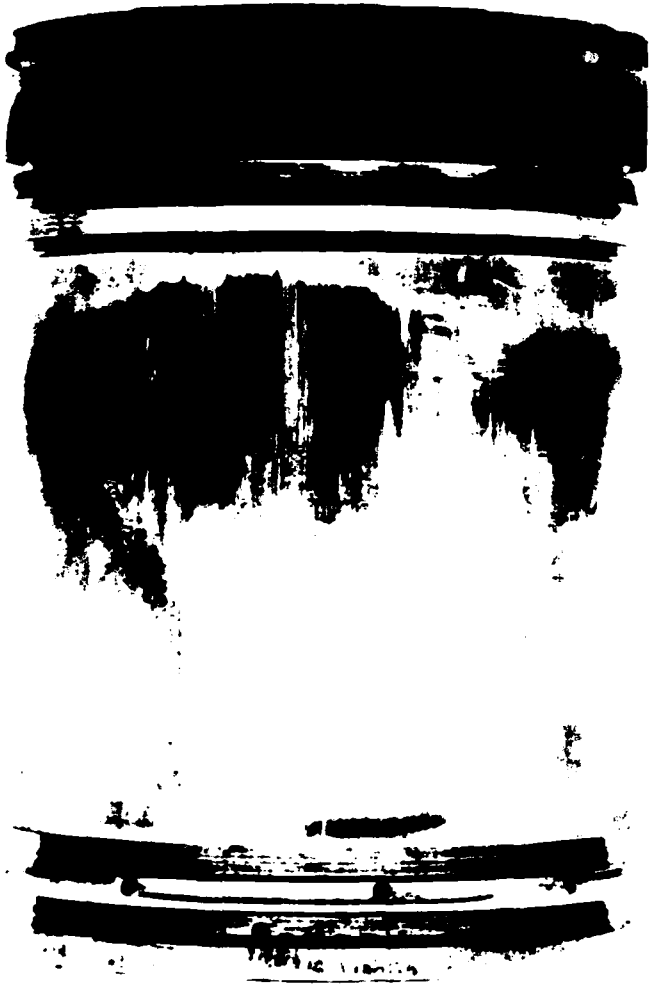


6V53T(#32)
3-L

6V53T(#32)
3-R



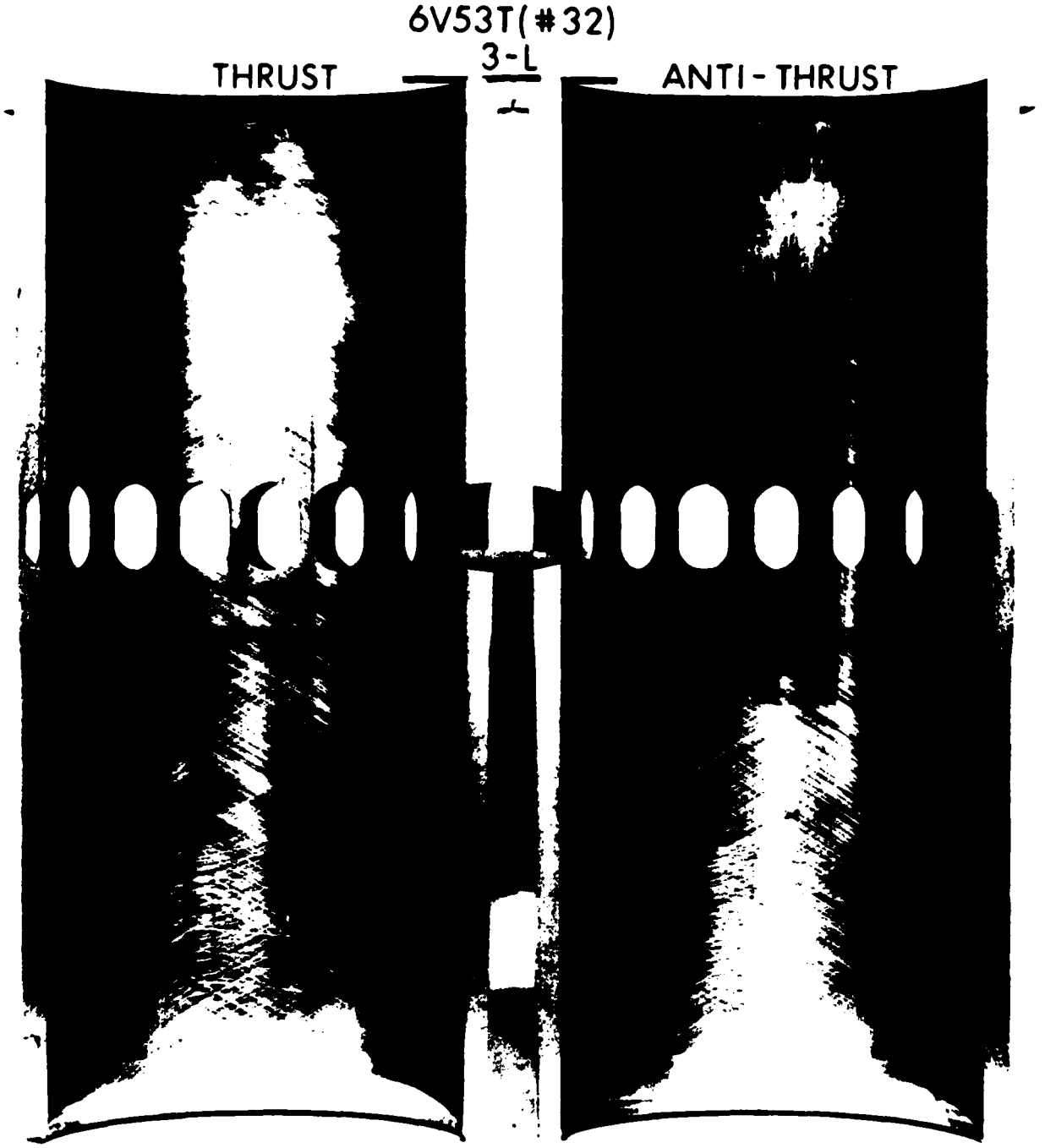
6V53T(#32)
3-L-T

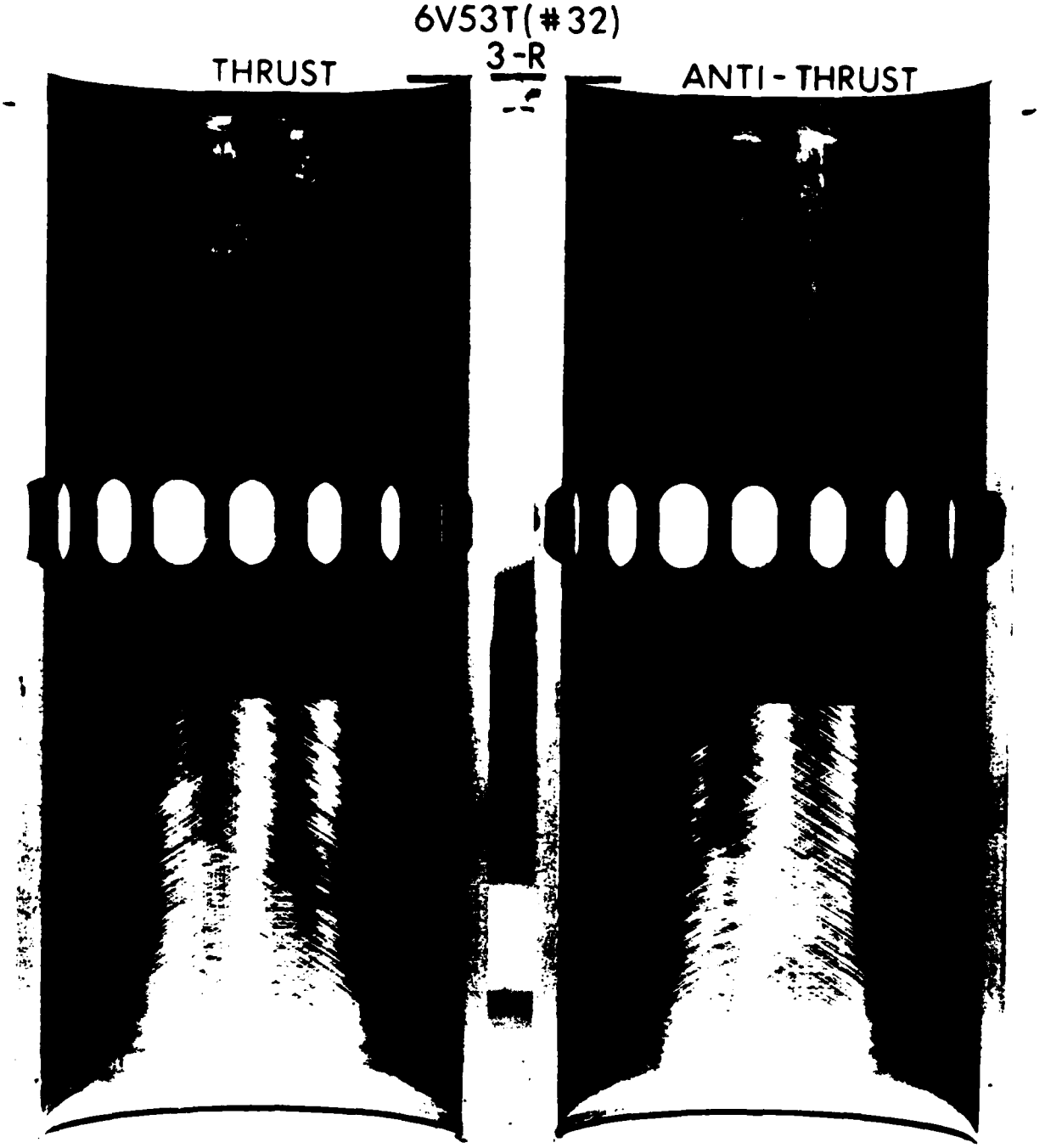


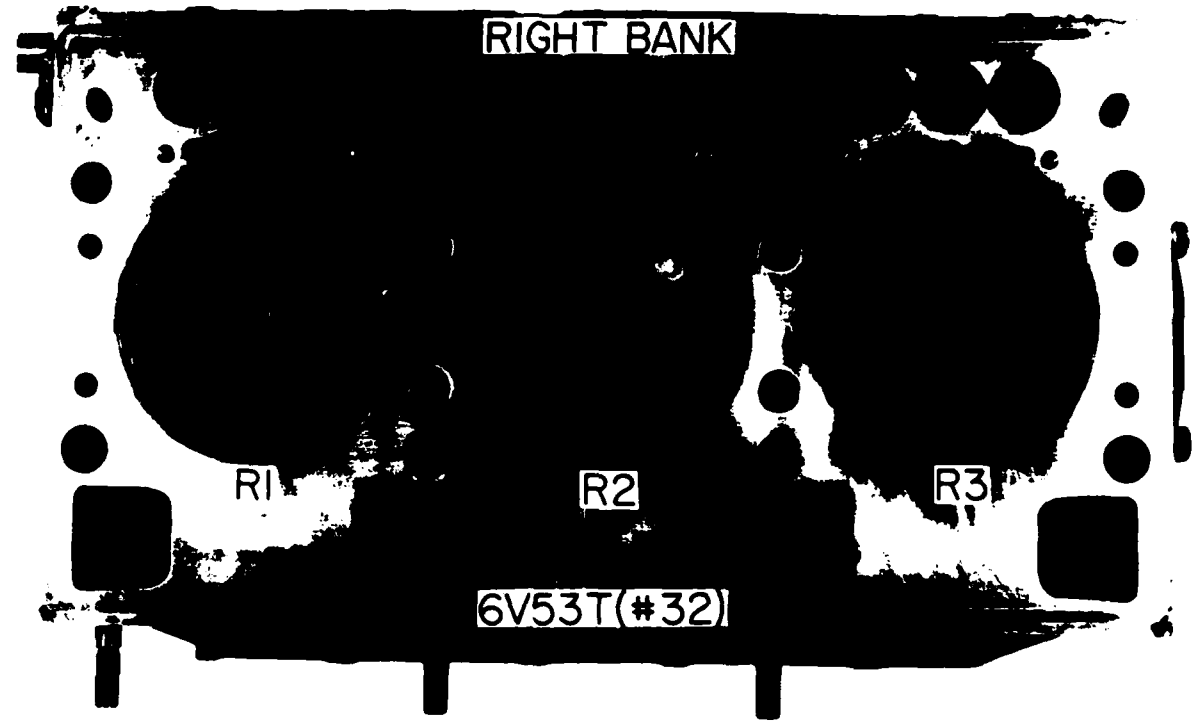
6V53T(#32)
3-L-AT

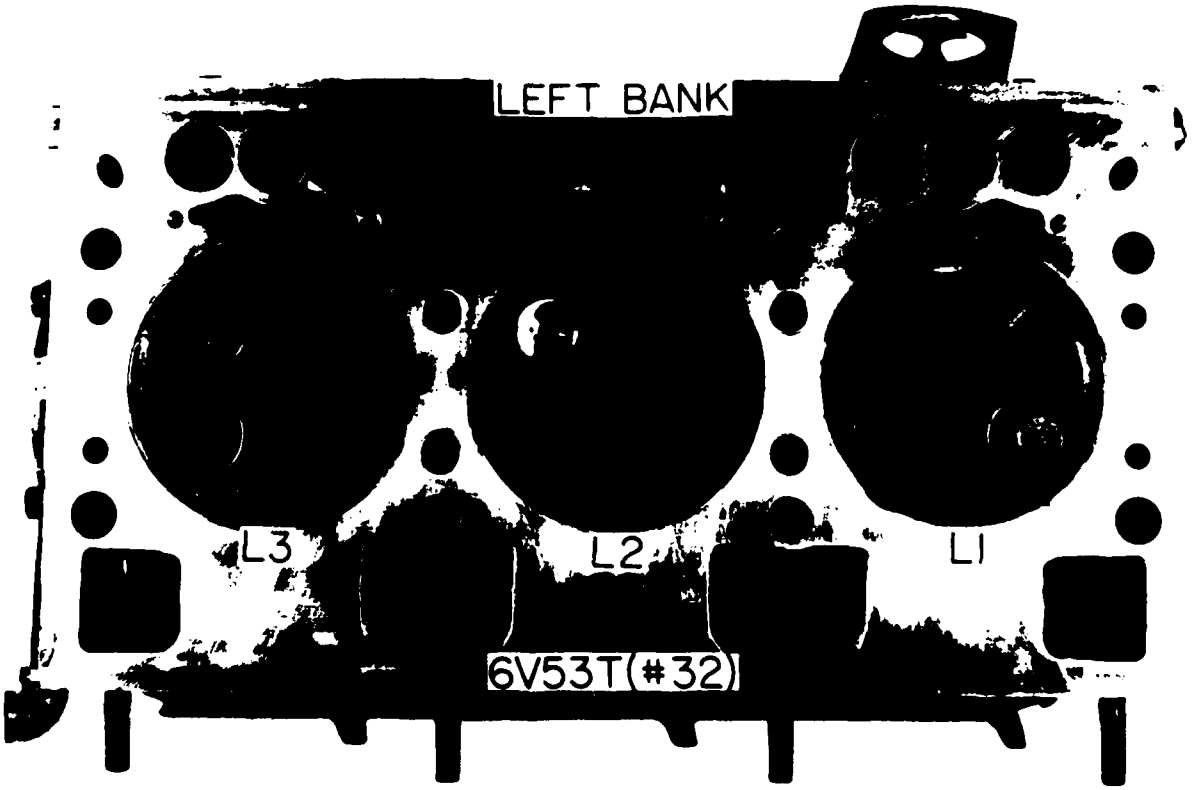
6V53T(#32)
3-R-T

6V53T(#32)
3-R-AT


6V53T(#32)
3-L
THRUST
ANTI-THRUST


6V53T(#32)
3-R
THRUST
ANTI-THRUST


RIGHT BANK
R1
R2
R3
6V53T(#32)


LEFT BANK
L3
L2
L1
6V53T(#32)

APPENDIX D

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL FUEL

Lubricant AL-12271-L, Test No. 34

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL ENGINE

Test Lubricant: AL-12272-L
Test Fuel: Caterpillar 1-H
Engine Test Number: 34
Date Completed: 30 August 1983

Conducted For

U.S. Army Mobility Equipment Research and Development Command
Materials, Fuels and Lubricants
Fort Belvoir, Virginia

By

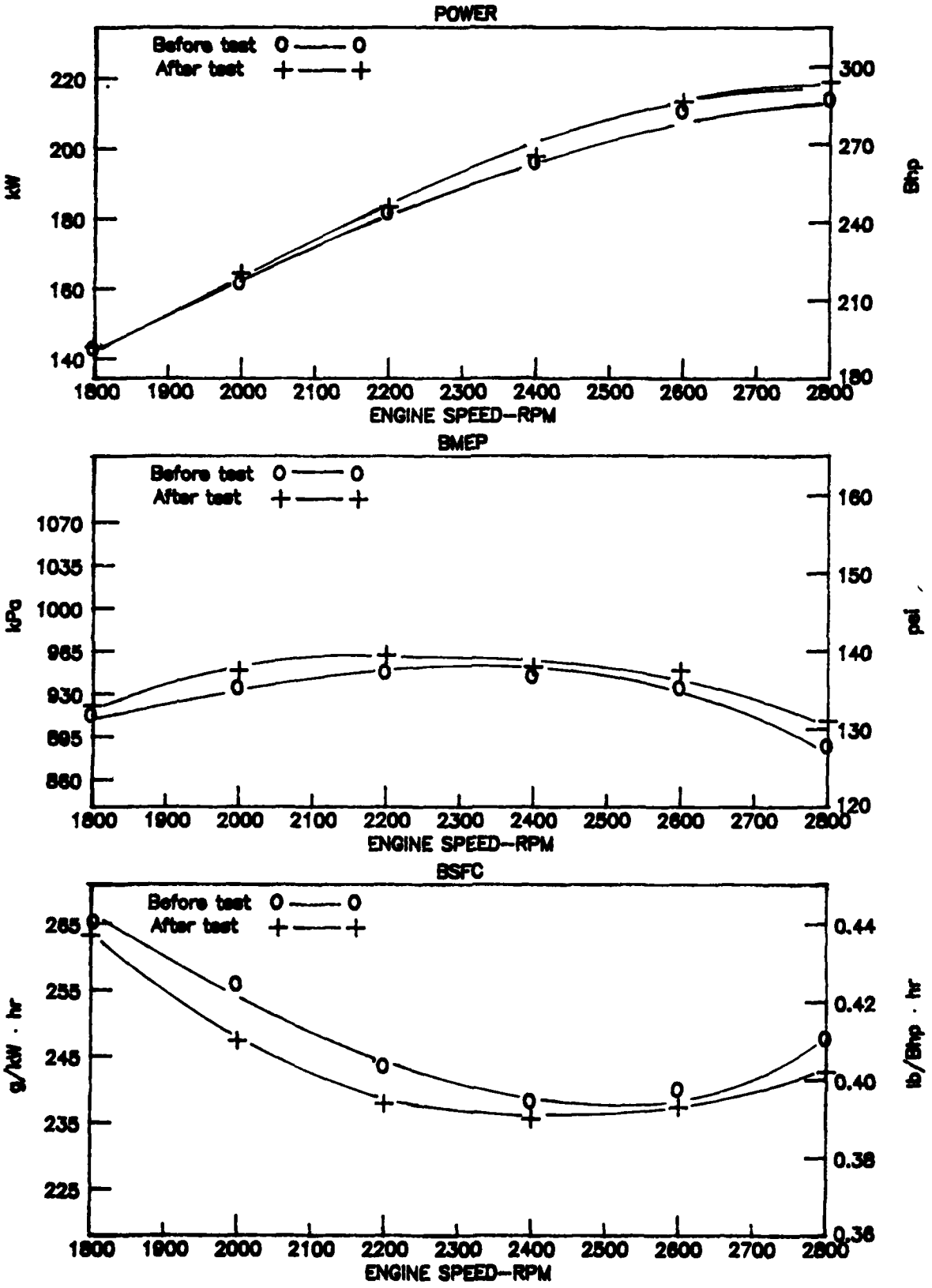
U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

6V-53T
TEST 34
ENGINE REBUILD MEASUREMENTS*
Model Number: 5063-5395
Serial Number: 6D-157211

	Min	Max	Avg	Specified Limits	
Cylinder Block Bore					
Inside Diameter (Bottom)	4.3565(110.655)	4.3580(110.693)	4.3573(110.675)	4.3565(110.655)	- 4.3575(110.681) New - 4.3595(110.731) Max
Out-of-Round	0.0000	0.0011(0.028)	0.0004(0.010)		- 0.0015(0.038) Max
Taper	0.0000	0.0010(0.025)	0.0004(0.010)		- 0.0015(0.038) Max
Cylinder Liners (Installed)					
Inside Diameter	3.8756(98.440)	3.8766(98.466)	3.8761(98.454)	3.8752(98.430)	- 3.8767(98.468)
Out-of-Round	0.0000	0.0004(0.010)	0.0001(0.003)		- 0.0015(0.038) Max
Taper	0.0000	0.0006(0.015)	0.0001(0.003)		- 0.0015(0.038) Max
Piston Diameter (at skirt)	3.8679(98.245)	3.8688(98.268)	3.8682(98.252)	3.8669(98.219)	- 3.8691(98.775)
Piston Skirt to Cylinder Liner Clearance	0.0073(0.185)	0.0084(0.213)	0.0080(0.203)	0.0061(0.155)	- 0.0098(0.249)
Compression Rings					
Gap (No. 1, Fire Ring)	0.029(0.74)	0.036(0.91)	0.033(0.84)	0.020(0.51)	- 0.046(1.17)
Gap (Nos. 2, 3, 4)	0.029(0.74)	0.036(0.91)	0.032(0.81)	0.020(0.51)	- 0.036(0.91)
Ring-to-Groove Clearance**					
Top (No. 1, Fire Ring)	0.003(0.08)	0.004(0.10)	0.004(0.10)	0.003(0.08)	- 0.006(0.15)
No. 2, Compression Ring	0.007(0.18)	0.008(0.20)	0.008(0.20)	0.007(0.18)	- 0.010(0.25)
No. 3 and 4, Compression Rings	0.005(0.13)	0.007(0.18)	0.006(0.15)	0.005(0.13)	- 0.008(0.20)
Oil Control Rings, Nos. 5, 6, 7					
Gap	0.016(0.41)	0.022(0.56)	0.018(0.46)	0.010(0.25)	- 0.025(0.64)
Ring-to-Groove Clearance	0.002(0.05)	0.004(0.10)	0.003(0.08)	0.0015(0.038)	- 0.0055(0.140)
Piston Pin					
Pin-to-Piston Bushing Clearance	0.0030(0.076)	0.0033(0.084)	0.0032(0.81)	0.0025(0.064)	- 0.0034(0.086)
Pin-to-Connecting Rod Bushing Clearance	0.0014(0.036)	0.0018(0.046)	0.0016(0.041)	0.0010(0.025)	- 0.0019(0.048)
Connecting Rod Bearing-to-Journal Clearance	0.0022(0.056)	0.0029(0.074)	0.0025(0.064)	0.0011(0.028)	- 0.0041(0.104)
Main Bearing-to-Journal Clearance	0.0032(0.081)	0.0033(0.084)	0.0033(0.084)	0.0010(0.025)	- 0.0040(0.102)
Camshaft Bearing-to-Journal Clearance	0.0050(0.127)	0.0054(0.137)	0.005(0.130)	0.0045(0.114)	- 0.0060(0.152)

* Measurements are in inches and (mm).

6V-53T 240-HOUR TRACKED VEHICLE CYCLE
BEFORE AND AFTER TEST 34 PERFORMANCE DATA



6V-53T
240-HOUR TRACKED VEHICLE CYCLE ENDURANCE TEST
TEST 34
OPERATING CONDITIONS SUMMARY

Lubricant: AL-12272-L Fuel: Caterpillar 1-H

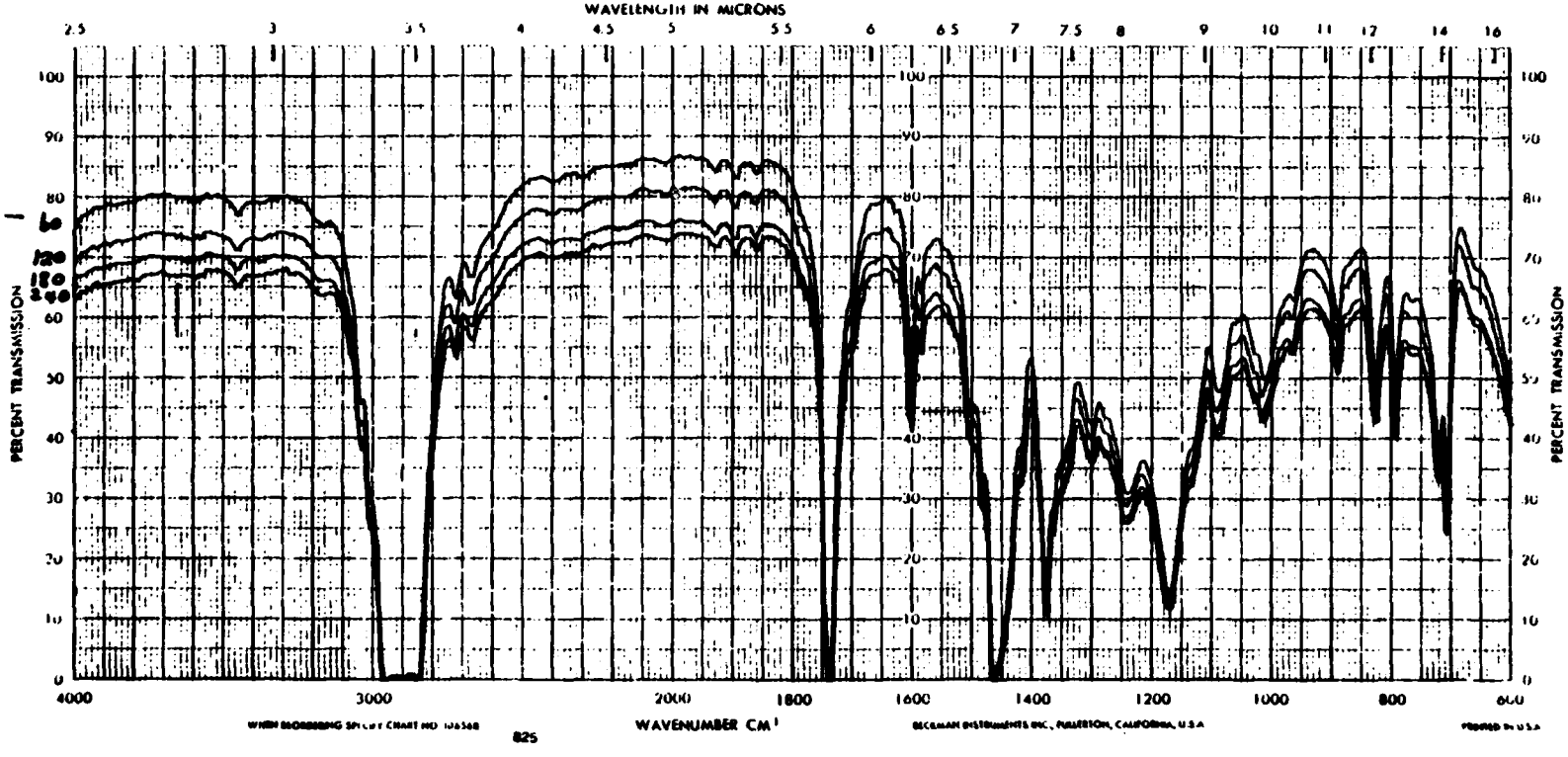
	Maximum Power Mode (2800 RPM)		Maximum Torque Mode (2200 RPM)	
	Mean	Standard Deviation	Mean	Standard Deviation
Engine Speed, rpm	2800	5.52	2200	4.77
Torque, ft-lb (N-m)	439(596)	2.99(4.05)	492(667)	10.90(14.8)
Fuel Consumption, lb/hr(kg/hr)	93.4(42.4	0.993(0.45)	77.1(35)	1.53(0.69)
Observed Power, Bhp(kW)	234(175)	1.62(1.21)	206(154)	4.60(3.44)
BSFC, lb/Bhp-hr(g/kW-hr)	0.400(243)	0.004(2.61)	0.375(228)	0.007(4.31)
Temperatures, °F(°C)				
Exhaust before Turbo	864(462)	22.60(12.6)	824(440)	23.40(13)
Exhaust after Turbo	711(377)	18.60(10.3)	729(387)	22.80(12.7)
Water Jacket Inlet	158(70.2)	1.97(1.10)	158(69.7)	1.16(0.64)
Water Jacket Outlet	170(76.8)	1.88(1.05)	170(76.4)	1.22(0.68)
Oil Sump	227(109)	2.23(1.24)	220(104)	2.31(1.28)
Fuel at Filter	94(34.6)	2.60(7.95)	91.4(33)	4.18(2.32)
Inlet Air	98(36.5)	4.58(2.55)	96.8(36)	4.21(2.34)
Airbox	258(125)	5.34(2.96)	216(102)	3.95(2.20)
Pressures				
Exhaust before Turbo, psi(kPa)	10.48(72.3)	0.09(0.62)	6.92(47.7)	0.12(0.84)
Exhaust after Turbo, in. Hg(kPa)	2.03(6.85)	0.89(3.01)	1.29(4.34)	0.45(1.50)
Compressor Discharge, psi(kPa)	10.33(71.2)	0.23(1.56)	7.00(48.3)	0.20(1.35)
Blower Discharge, psi(kPa)	15.06(104)	0.44(3.05)	8.39(57.9)	0.49(3.40)
Oil Gallery, psi (kPa)	51.75(357)	0.41(2.83)	45.1(311)	0.58(3.99)
Intake Vacuum, in. H_2O(kPa)	6.78(1.69)	0.16(0.04)	3.89(0.97)	0.12(0.03)
Ambient Conditions				
Dry Bulb Temperature, °F(°C)	83.1(28.4)	5.38(2.99)	83.2(28.4)	4.87(2.71)
Wet Bulb Temperature, °F(°C)	77.6(25.3)	7.09(3.94)	77.3(25.2)	6.42(3.56)
Barometric Pressure, in. Hg(kPa) (Both modes of operation)	29.1(98.3)	0.09(0.30)		

*68% of the values for a given variable occur within ±1 standard deviation of the mean; 95% occur within ±2 standard deviations.

6V-53T
TEST 34
LUBRICANT ANALYSIS
Lubricant: AL-12272-L

	ASTM Test Method	Test Time, Hours 0	20	40	60	80	100	120	140	160	180	200	220	240
Kinematic viscosity at 40°C (104°F) cSt	D 445	32.0	--	--	30.32	--	--	30.42	--	--	29.78	--	--	29.87
Kinematic viscosity at 100°C (212°F) cSt	D 445	6.37	5.95	5.89	5.77	5.89	5.88	5.91	5.84	5.73	5.82	5.83	5.82	5.82
Total Acid Number mg KOH/g	D 664	2.10	--	--	2.20	--	--	2.25	--	--	2.31	--	--	2.32
Total Base Number mg KOH/g	D 664	7.91	--	--	3.30	--	--	3.00	--	--	4.22	--	--	4.30
Pentane B Insolubles wt%	D 893	0.0	--	--	0.02	--	--	0.06	--	--	0.06	--	--	0.07
Toluene B Insolubles wt%	D 893	0.0	--	--	0.02	--	--	0.05	--	--	0.05	--	--	0.06
Flash Point, °C	D 92	229	--	--	--	--	--	232	--	--	--	--	--	229

INFRARED SPECTRUM
6V-53T
TEST 34
LUBRICANT: AL-12272-L



6V-53T
TEST 34
Lubricant: AL-12272-L

TOTAL CONSUMPTION AND WEAR METALS BY XRF

Test Time, Hours	Total Oil Consumed, lb(kg)		Wear Metals, ppm Fe	Cu
0			44	<10
20	6.80	(3.08)	77	<10
40	14.50	(6.58)	83	<10
60	23.30	(10.57)	89	17
80	30.12	(13.66)	70	<10
100	39.88	(18.09)	83	<10
120	Oil Change		81	15
140	46.32	(21.01)	37	<10
160	57.41	(26.04)	47	<10
173	60.78	(27.57)		
180	72.06	(32.69)	68	<10
185.5	79.19	(35.92)		
187.5	86.55	(39.26)		
190	93.81	(42.55)		
200	106.75	(48.42)	157	<10
220	116.54	(52.86)	128	<10
240	129.63	(58.80)	110	<10

Average oil consumption rate: 0.54 lb/hr (0.24 kg/hr)

6V-53T
TEST 34
Lubricant: AL-12272-L

WEAR MEASUREMENTS*

Cylinder Liner Bore Diameter Change

	Cylinder Number 1L		2L		3L	
	T-AT**	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0007 (0.018)	+0.0002 (0.005)	+0.0004 (0.010)	+0.0001 (0.003)	+0.0014 (0.036)	-0.0003 (-0.008)
Middle	+0.0004 (0.010)	-0.0003 (-0.008)	0.0000	-0.0001 (-0.003)	+0.0004 (0.010)	-0.0002 (-0.005)
Bottom	0.0000	-0.0005 (-0.013)	+0.0007 (0.018)	+0.0001 (0.003)	+0.0002 (0.005)	+0.0001 (0.003)

	Cylinder Number 1R		2R		3R	
	T-AT*	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0018(0.046)	+0.0002(0.005)	-0.0001(-0.003)	+0.0006(0.015)	+0.0039(0.099)	+0.0031(0.079)
Middle	+0.0004(0.010)	+0.0003(0.008)	+0.0005(0.013)	+0.0004(0.010)	+0.0017(0.043)	+0.0014(0.036)
Bottom	-0.0003(-0.008)	+0.0001(0.003)	-0.0001(-0.003)	-0.0003(-0.008)	+0.0001(0.003)	0.0000

Average Change

	T-AT	F-B
Top	+0.0014 (0.036)	+0.0007 (0.018)
Middle	+0.0006 (0.015)	+0.0003 (0.008)
Bottom	+0.0001 (0.003)	-0.0001 (-0.003)

Overall average change: +0.0005 (0.013)

Piston Ring End Gap Change

Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1	0.000	0.000	+0.001(0.03)	+0.001(0.03)	0.000	+0.007(0.18)	+0.002(0.05)
2	0.000	-0.001(-0.03)	+0.001(0.03)	0.000	0.000	0.000	0.000
3	0.000	0.000	+0.001(0.03)	0.000	0.000	-0.003(-0.08)	0.000
4	0.000	0.000	+0.001(0.03)	0.000	0.000	-0.001(-0.03)	0.000
5	+0.006(0.15)	+0.004(0.10)	+0.004(0.10)	+0.006(0.15)	+0.006(0.15)	+0.012(0.30)	+0.006(0.15)
6	0.000	+0.001(0.03)	0.000	+0.002(0.05)	+0.004(0.10)	+0.006(0.15)	+0.002(0.05)
7	0.000	0.000	-0.001(-0.03)	+0.005(0.13)	+0.002(0.05)	+0.003(0.08)	+0.002(0.05)

Overall average change: +0.002(0.05)

*All dimensions are given in inches (mm).
**T-AT = Thrust-Antithrust Direction; F-B = Front-Back Direction.

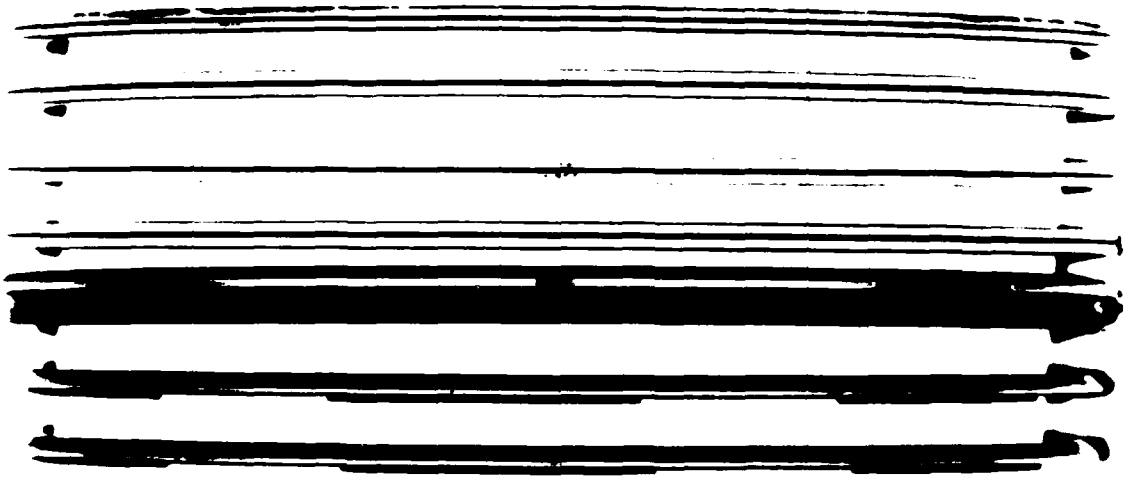
6V-53T
TEST 34
Lubricant: AL-12272-L
POST TEST ENGINE CONDITION AND DEPOSITS

	1L	2L	3L	1R	2R	3R	Average
A. Cylinder Liner							
Intake Port Plugging, % restriction	<1	<1	<1	<1	<1	<1	<1
Liner Scuffing, % Area							
Thrust	3.00	0.00	26.00	88.00	43.00	100.00	43.33
Anti-Thrust	2.00	5.00	9.00	26.00	23.00	82.00	24.50
% Total Area Scuffed	2.50	2.50	17.50	57.00	33.00	91.00	33.92
						Overall:	33.92
% Area Bore Polished							
Thrust	1.00	1.00	1.00	0.00	2.00	0.00	0.83
Anti-Thrust	5.00	2.00	2.00	7.00	2.00	1.00	3.17
% Avg. Area Bore Polished	3.00	1.50	1.50	3.50	2.00	0.50	2.00
						Overall:	2.00
B. Pistons							
Ring Face Distress, (demerits)							
No. 1	10.50	9.50	29.25	25.25	30.50	65.00	28.33
No. 2	0.00	1.50	14.25	34.00	17.75	55.00	20.42
No. 3	0.00	1.00	28.75	32.50	25.00	61.25	24.75
						Overall:	24.50
Piston Skirt Rating							
Thrust	S*	S	15%SC	40%SC	5%SC	35%SC	
Anti-Thrust	S	S	S	5%SC	<5%SC	30%SC	
Piston WTD Rating**	242.50	220.75	240.63	225.88	200.00	266.38	232.69
Ring Sticking							
No. 1	← Free →						
No. 2	← Free →						
No. 3	← Free →						
C. Exhaust Valves							
Deposits							
Head	BHC+	AHC	½AHC	CHC	BHC	AHC	
Face	½AHC	½AHC	½AHC	½AHC	½AHC	½AHC	
Tulip	½AHC	½AHC	½AHC	½AHC	½AHC	½AHC	
Stem	½AHC	½AHC	½AHC	½AHC	½AHC	½AHC	
	#9++	#9	#9	#9	#9	#9	
Surface Condition							
Freeness in Guide	F	F	F	F	F	F	
Head	← Normal →						
Face	← Normal →						
Seat	← Normal →						
Stem	← Some medium to heavy wear with scuffing →						
Tip	← Normal →						
D. Other Ratings							
Upper Oil Control Ring Expansive Force, lbs.	19.2	20.0	20.2	19.4	19.4	19.4	19.6

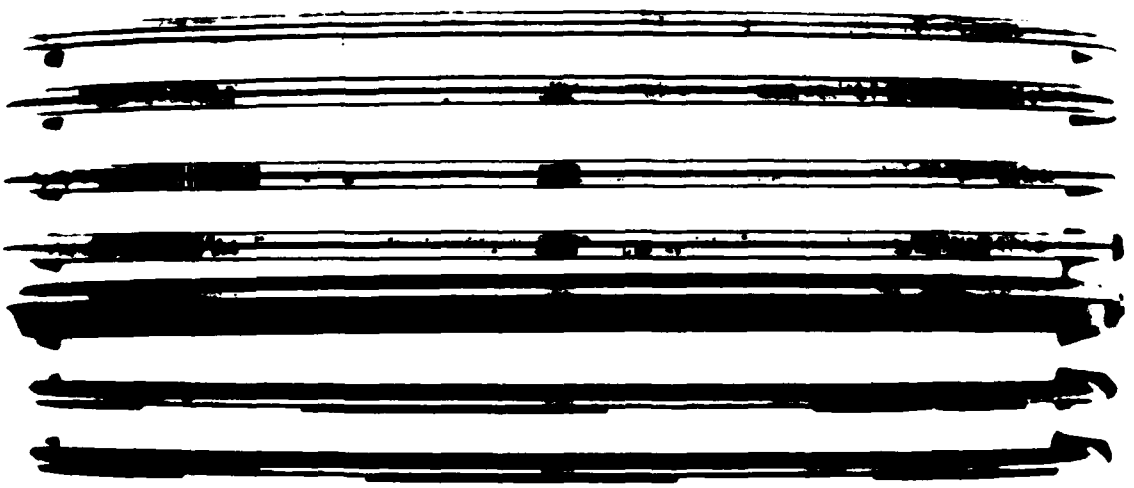
Bearing Surface Condition	
Main Bearings	# 2 main bearing worn to copper; rest have scratches
Rod Bearings	1L connecting rod bearing worn to copper; rest have some scratches
Camshaft Bearings	#2 camshaft bearing spun in housing, wiped bearing material and deposited it in the oil hole of the shaft. (Plugged)
Tappets, Cams and Rocker Arm Condition	Some moderate to heavy scoring on camshaft lobes and tappet rollers.

*L = Light, S = Scratches, PM = Plating Melted, N = Normal, SC = Scuffing, B = Burn
**CRC Weighted Total Deposits (0 = least, 900 = most)
+HC = Hard Carbon; the number-letter, prefix indicates carbon depth with ½A = least to J = most
++ = Lacquer; the higher the number, the darker the lacquer (0 = lightest, 9 = darkest)

6V53T
1-1-1-34
1-L



6V53T
1-1-1-34
1-R

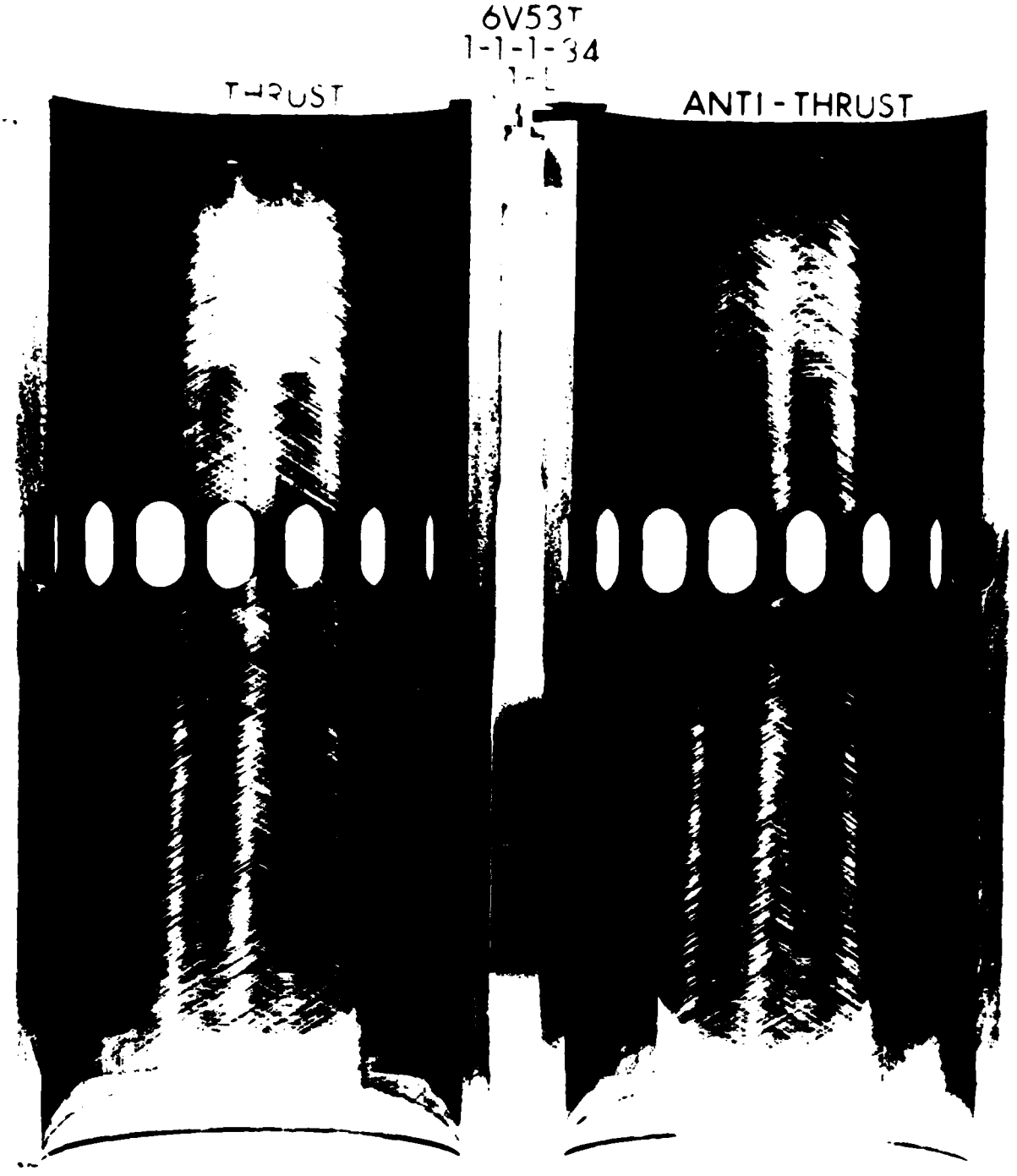


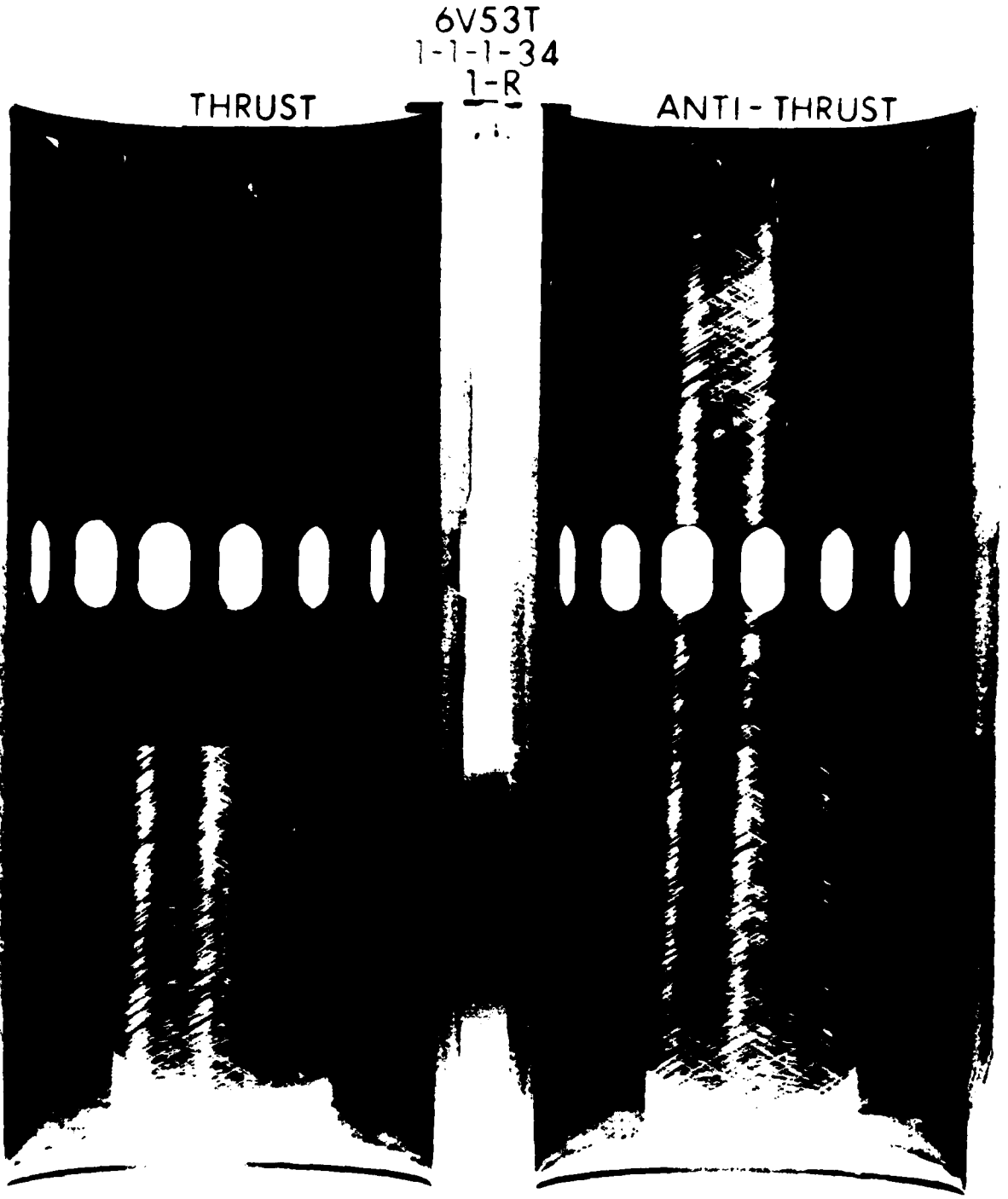
6V53T
1-1-1-34
1-L-AT

6V53T
1-1-1-34
1-L-T

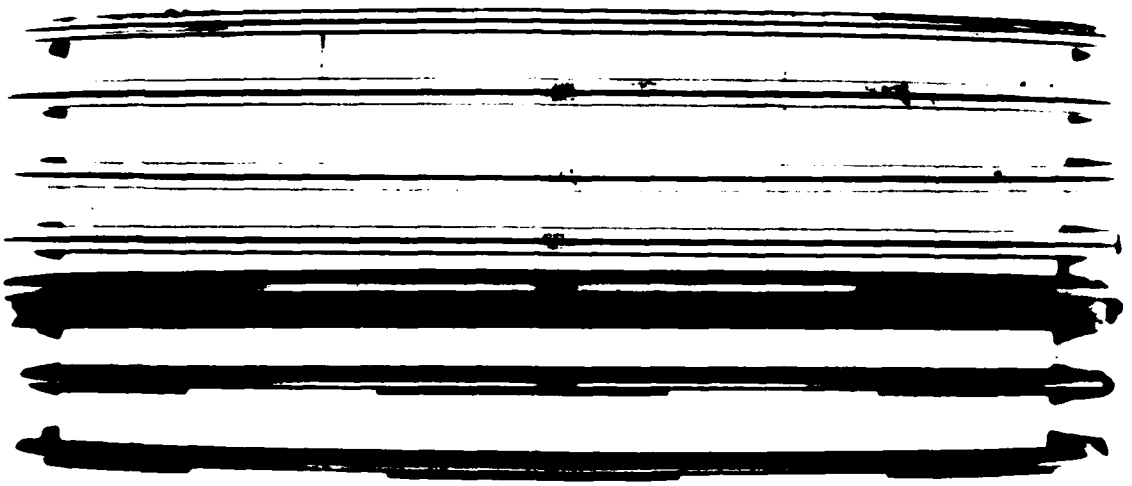
6V53T
1-1-1-34
1-R-T

6V53T
1-1-1-34
1-R-AT


6V53T
1-1-1-34
THRUST
ANTI - THRUST


6V53T
1-1-1-34
1-R
THRUST
ANTI - THRUST

6V53T
1-1-1-34
2-L



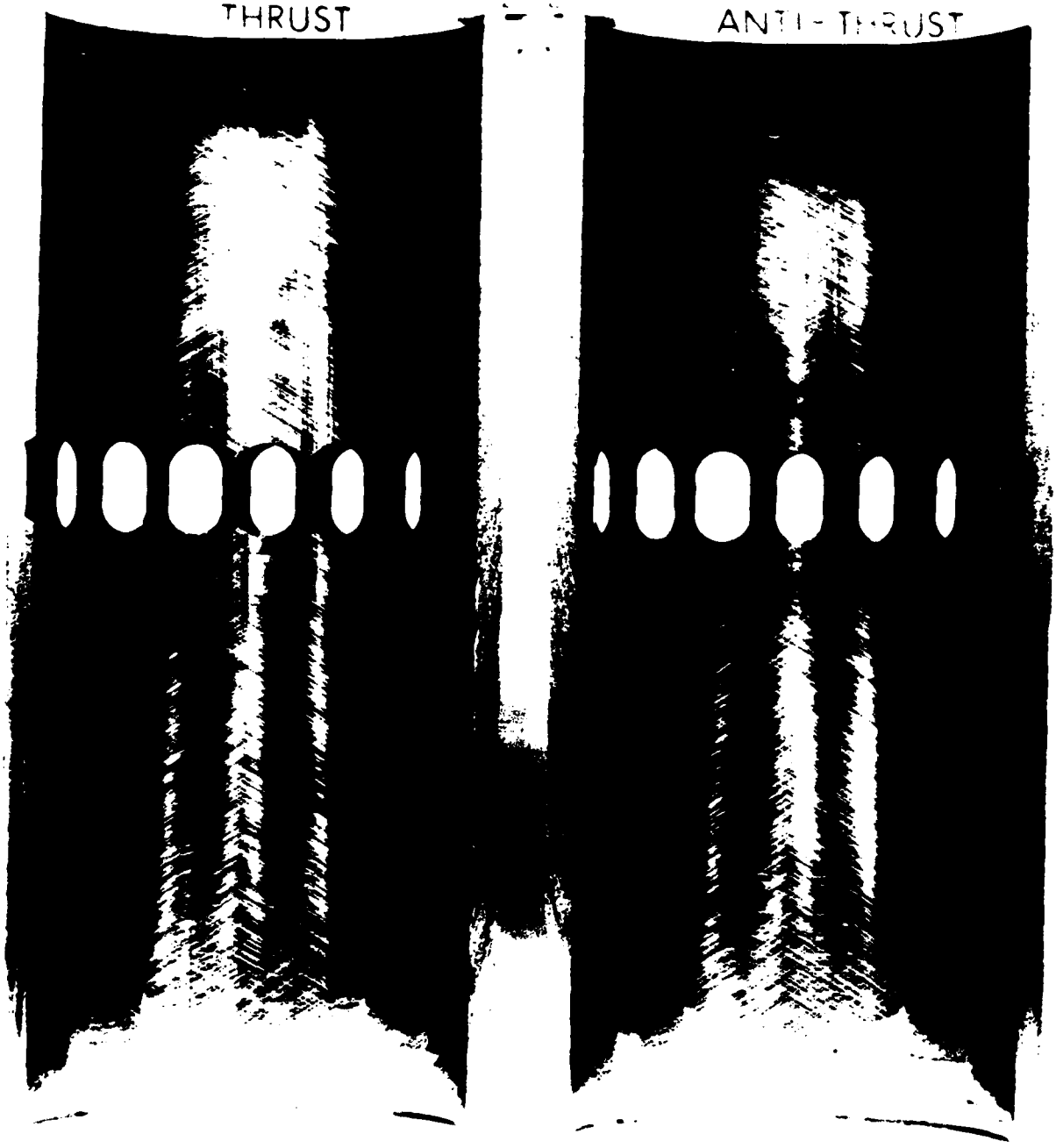
6V53T
1-1-1-34
2-R

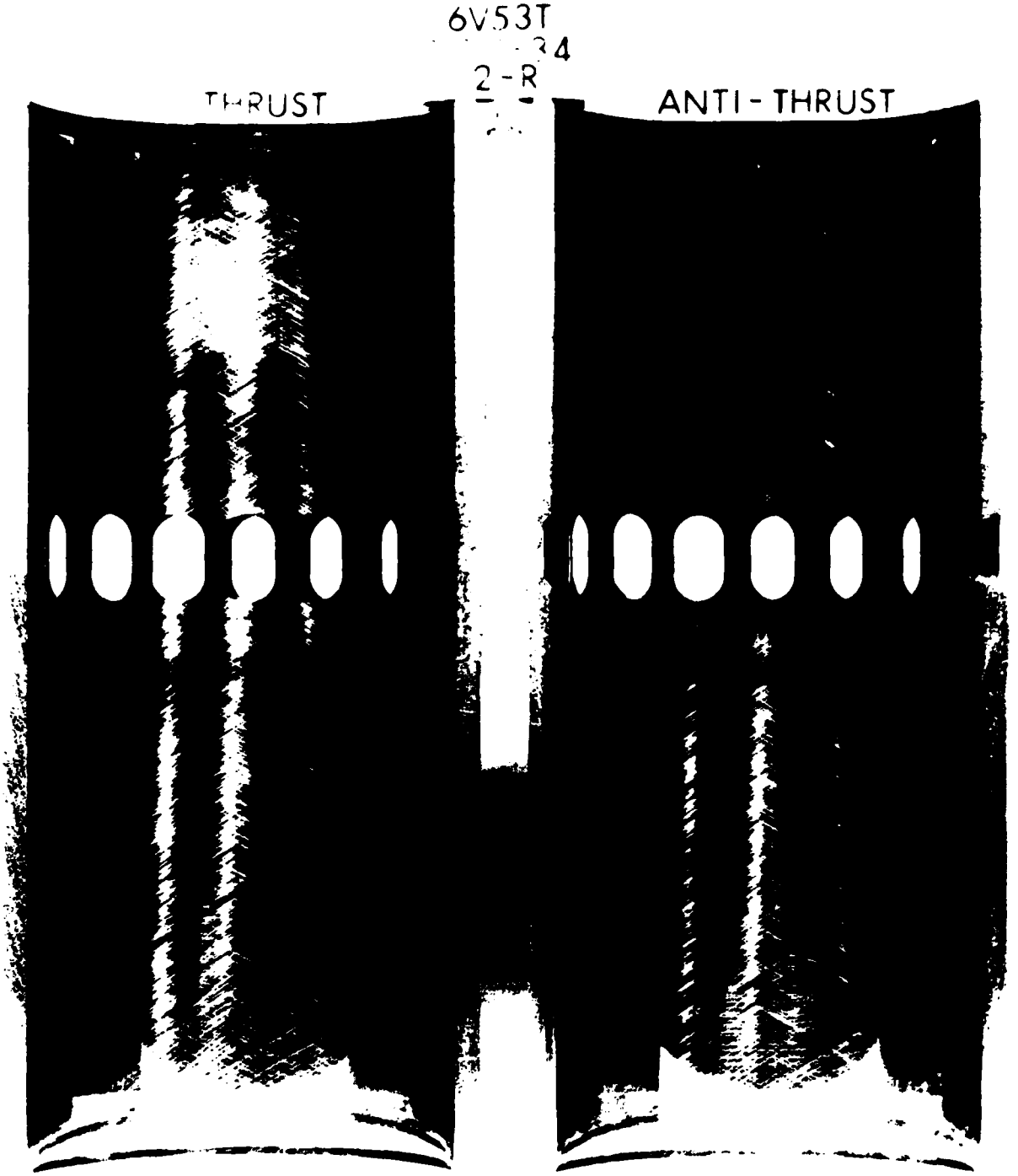
6V53T
1-1-1-34
2-L-T

6V53T
1-1-1-34
2-L-AT

6V53T
1-1-1-34
2-R-AT

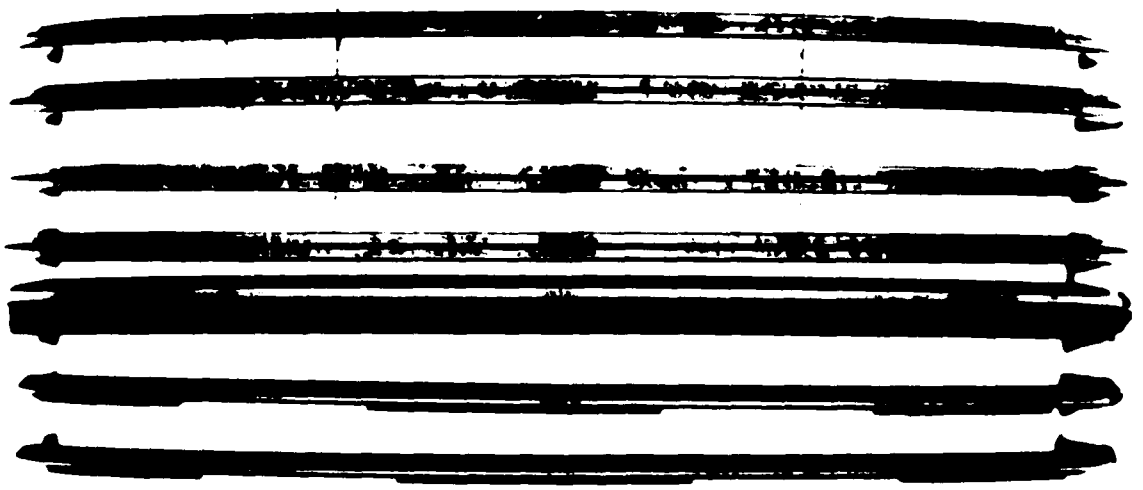
6V53T
1-1-1-34
2-R-T


THRUST
ANTI-THRUST


6V53T
2-R
THRUST
ANTI-THRUST

6V53T
1-1-1-34
3-L

6V53T
1-1-1-34
3-R

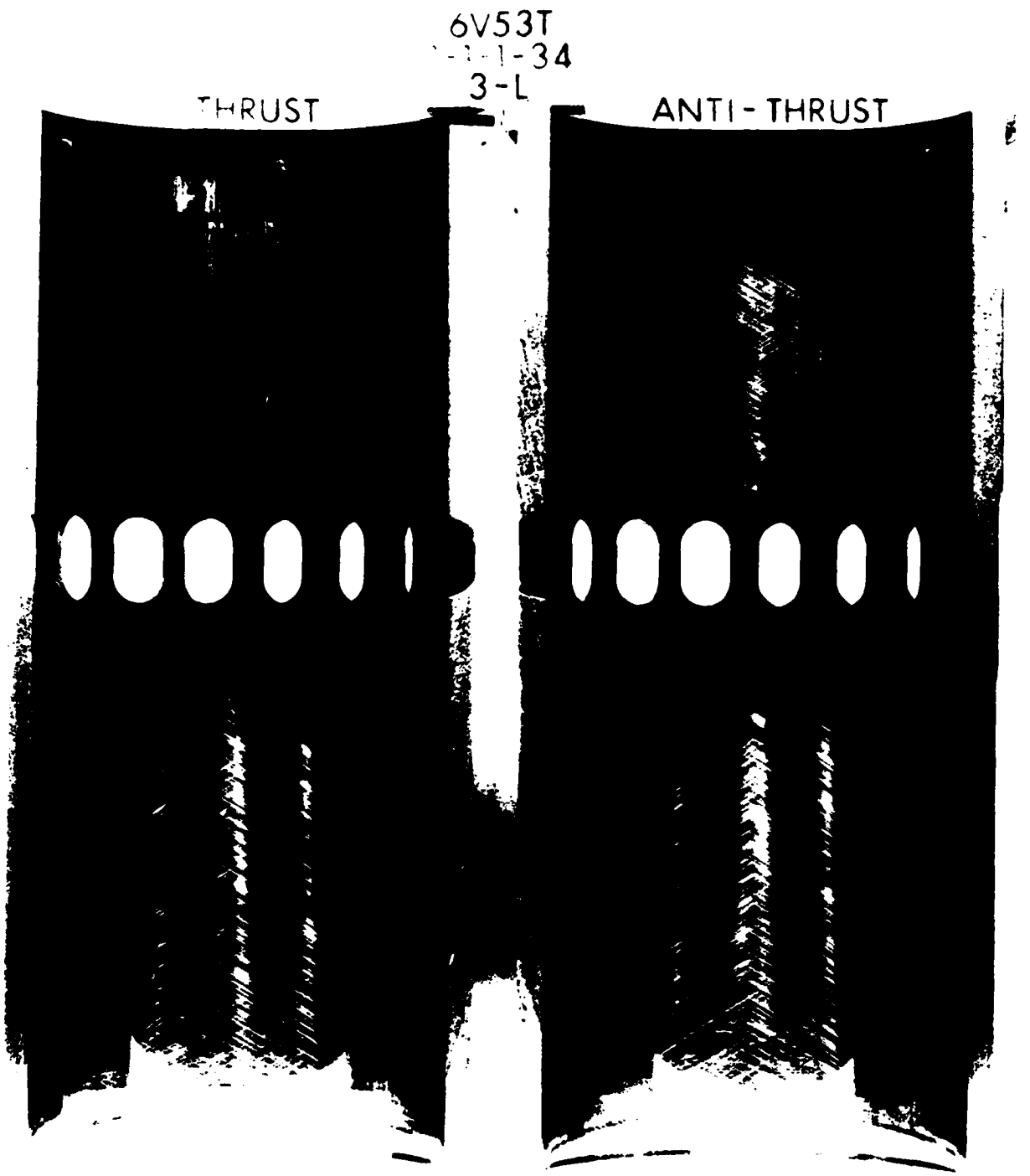


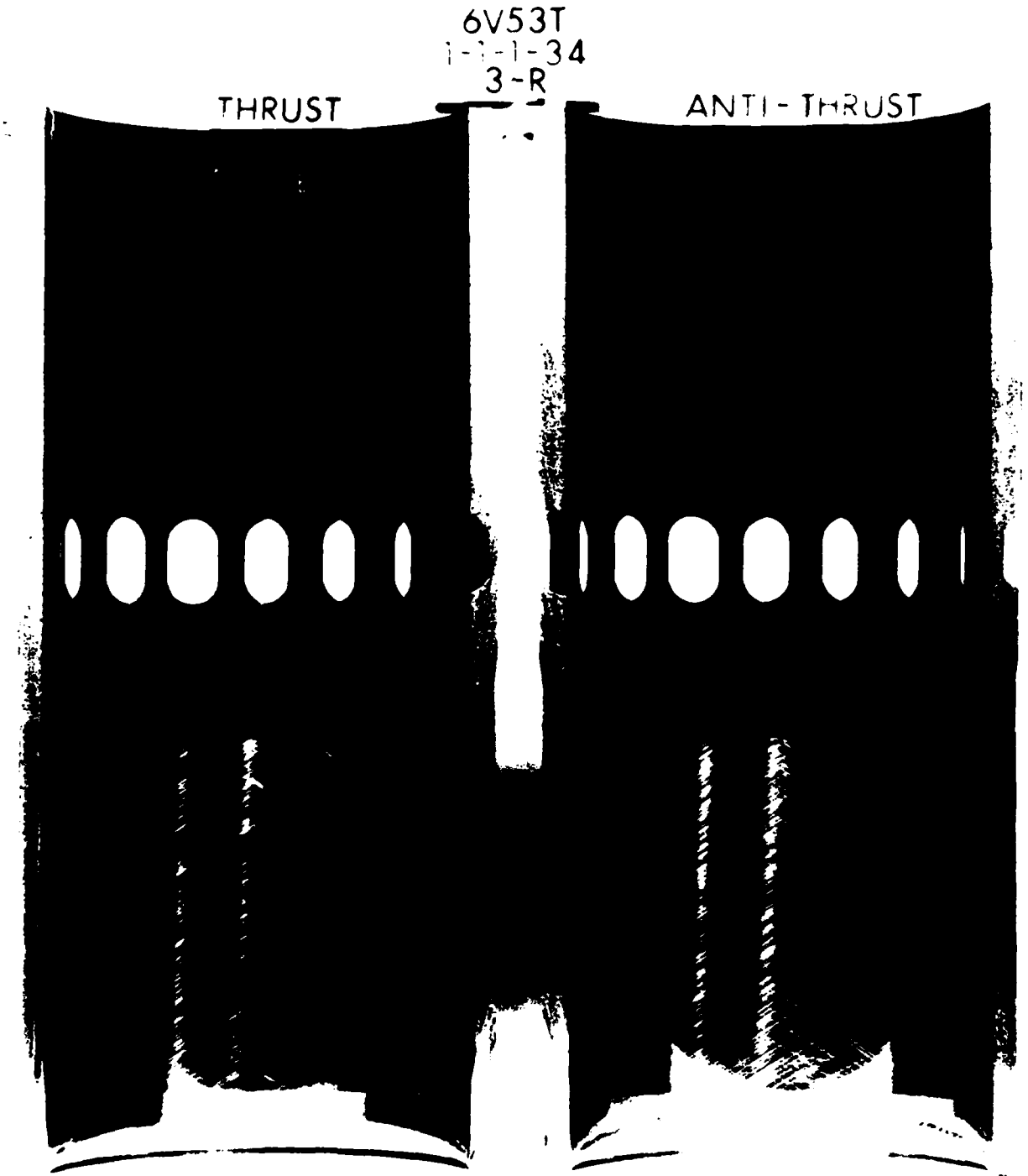
6V53T
1-1-1-34
3-L-AT

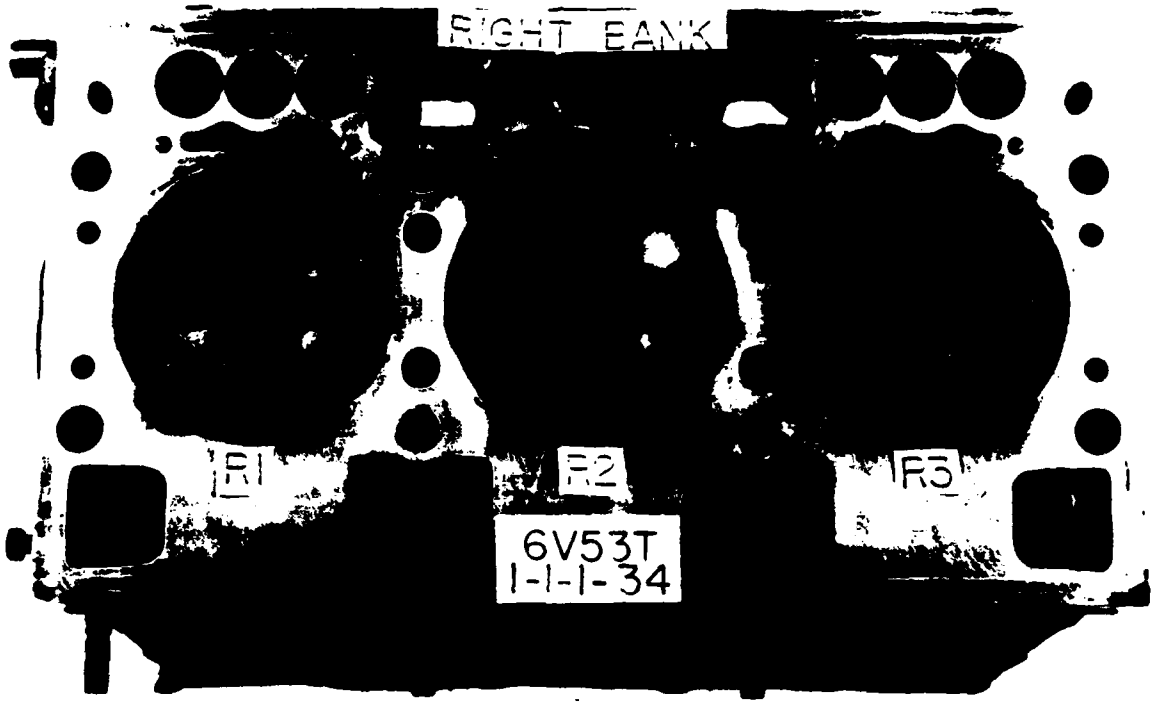
6V53T
1-1-1-34
3-L-T

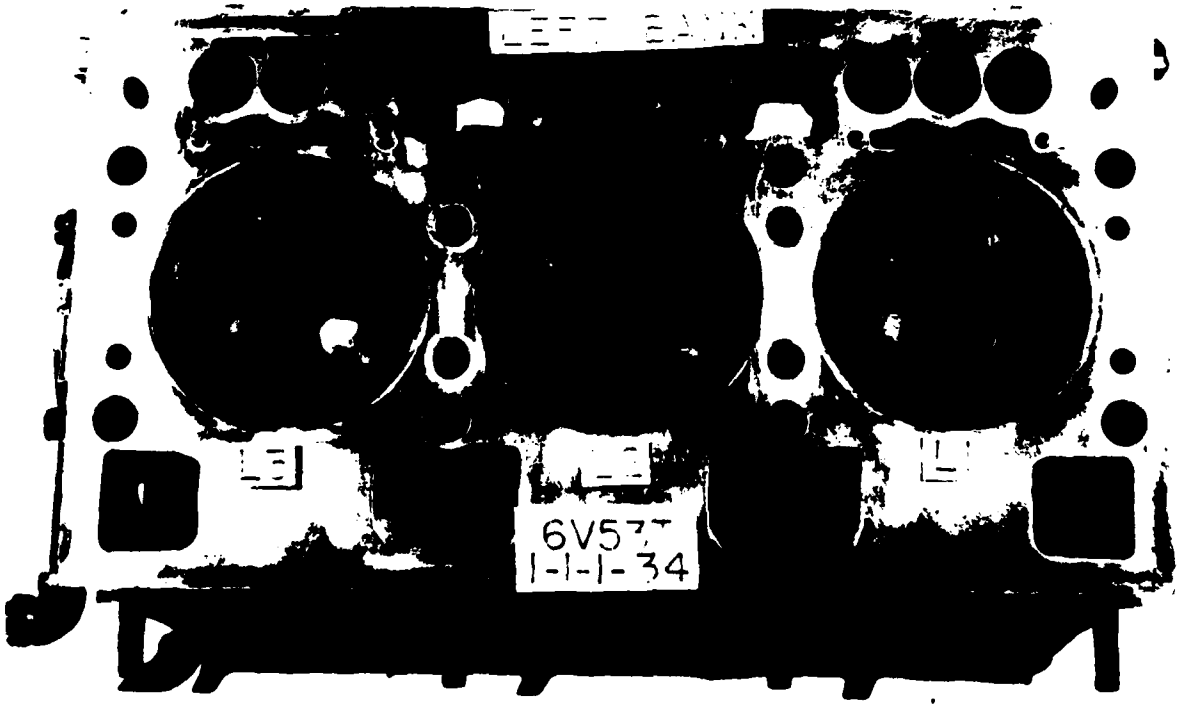
6V53T
1-1-1-34
3-R-T

6V53T
1-1-1-34
3-R-AT


6V53T
-1-1-34
3-L
THRUST
ANTI-THRUST


6V53T
1-1-1-34
3-R
THRUST
ANTI-THRUST


RIGHT BANK
R1
R2
R3
6V53T
1-1-1-34


L3
6V53T
1-1-1-34

APPENDIX E

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL FUEL

Lubricant AL-12186-L, Test No. 35

ENGINE-LUBRICANT COMPATIBILITY TEST
240-HOUR TRACKED-VEHICLE CYCLE
USING 6V-53T DIESEL ENGINE

Test Lubricant: AL-12186-L
Test Fuel: Caterpillar 1-H
Engine Test Number: 35*
Date Completed: 12 September 1983

Conducted For

U.S. Army Mobility Equipment Research and Development Command
Materials, Fuels and Lubricants
Fort Belvoir, Virginia

By

U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas 78284

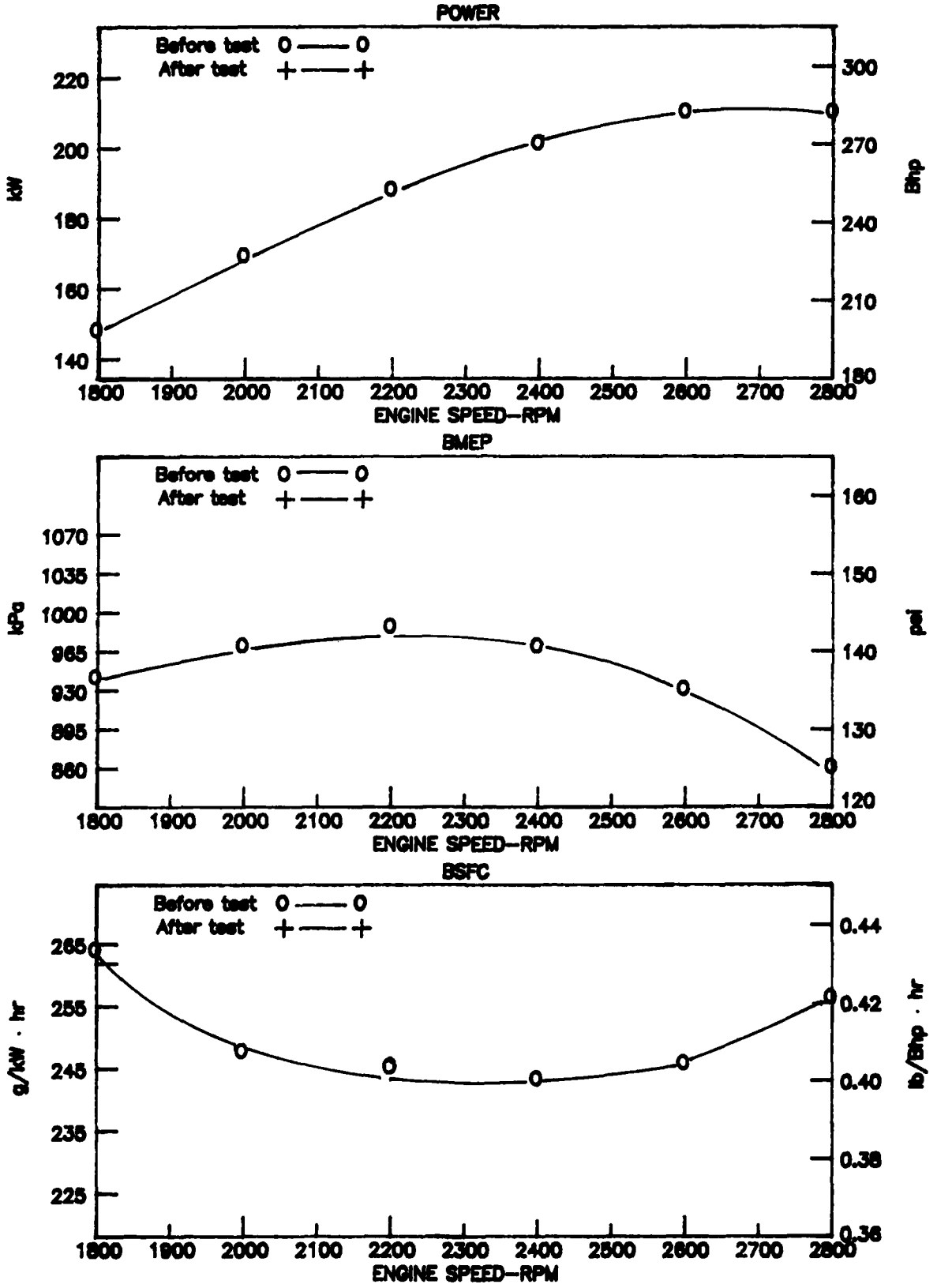
*Test stopped at 20 hours due to severe cylinder liner scuffing and high Fe content in the oil.

6V-53T
TEST 35
ENGINE REBUILD MEASUREMENTS*
Model Number: 5063-5395
Serial Number: 6D-178671

	Min	Max	Avg	Specified Limits	
Cylinder Block Bore					
Inside Diameter (Bottom)	4.3571(110.670)	4.3588(110.714)	4.3580(110.693)	4.3565(110.655)	- 4.3575(110.681) Ne - 4.3595(110.731) Ma
Out-of-Round	0.0001(0.003)	0.0019(0.048)	0.0009(0.023)		- 0.0015(0.038) Max
Taper	0.0001(0.003)	0.0010(0.025)	0.0008(0.020)		- 0.0015(0.038) Max
Cylinder Liners (Installed)					
Inside Diameter	3.8758(98.445)	3.8768(98.471)	3.8762(98.455)	3.8752(98.430)	- 3.8767(98.468)
Out-of-Round	0.0000	0.0006(0.015)	0.0002(0.005)		- 0.0015(0.038) Max
Taper	0.0001(0.003)	0.0006(0.015)	0.0003(0.008)		- 0.0015(0.038) Max
Piston Diameter (at skirt)	3.8675(98.23)	3.8681(98.250)	3.8678(98.242)	3.8669(98.219)	- 3.8691(98.775)
Piston Skirt to Cylinder Liner Clearance	0.0078(0.198)	0.0089(0.226)	0.0084(0.213)	0.0061(0.155)	- 0.0098(0.249)
Compression Rings					
Gap (No. 1, Fire Ring)	0.030(0.76)	0.033(0.84)	0.032(0.81)	0.020(0.51)	- 0.046(1.17)
Gap (Nos. 2, 3, 4)	0.028(0.71)	0.034(0.86)	0.030(0.76)	0.020(0.51)	- 0.036(0.91)
Ring-to-Groove Clearance**					
Top (No. 1, Fire Ring)	0.003(0.08)	0.004(0.10)	0.004(0.10)	0.003(0.08)	- 0.006(0.15)
No. 2, Compression Ring	0.007(0.18)	0.008(0.20)	0.008(0.20)	0.007(0.18)	- 0.010(0.25)
No. 3 and 4, Compression Rings	0.006(0.15)	0.006(0.15)	0.006(0.15)	0.005(0.13)	- 0.008(0.20)
Oil Control Rings, Nos. 5, 6, 7					
Gap	0.012(0.30)	0.016(0.41)	0.013(0.33)	0.010(0.25)	- 0.025(0.64)
Ring-to-Groove Clearance	0.002(0.05)	0.004(0.10)	0.003(0.08)	0.0015(0.038)	- 0.0055(0.140)
Piston Pin					
Pin-to-Piston Bushing Clearance	0.0029(0.074)	0.0032(0.081)	0.0031(0.079)	0.0025(0.064)	- 0.0034(0.086)
Pin-to-Connecting Rod Bushing Clearance	0.0015(0.038)	0.0019(0.048)	0.0017(0.043)	0.0010(0.025)	- 0.0019(0.048)
Connecting Rod Bearing-to-Journal Clearance	0.0013(0.033)	0.0021(0.053)	0.0018(0.046)	0.0011(0.028)	- 0.0041(0.104)
Main Bearing-to-Journal Clearance	Not measured				
Camshaft Bearing-to-Journal Clearance	Not measured				

* Measurement is in inches and (mm).

6V-53T 240-HOUR TRACKED VEHICLE CYCLE
BEFORE TEST 35 PERFORMANCE DATA



6V-53T
240-HOUR TRACKED VEHICLE CYCLE ENDURANCE TEST
TEST 35
OPERATING CONDITIONS SUMMARY

Lubricant: AL-12186-L Fuel: Caterpillar 1-H

	Maximum Power Mode (2800 RPM)		Maximum Torque Mode (2200 RPM)	
	Mean	Standard Deviation	Mean	Standard Deviation
Engine Speed, rpm	2800	4.18	2200	3.58
Torque, ft-lb (N-m)	442(599)	2.36(3.19)	498(675)	2.77(3.74)
Fuel Consumption, lb/hr(kg/hr)	97.2(44.1)	1.76(0.80)	81.1(36.8)	0.77(0.35)
Observed Power, Bhp(kW)	235(176)	1.46(1.09)	208(156)	1.10(0.82)
BSFC, lb/Bhp-hr(g/kW-hr)	0.413(251)	0.007(4.25)	0.390(237)	0.005(2.98)
Temperatures, °F(°C)				
Exhaust before Turbo	842(450)	20.90(11.6)	817(436)	20.8(11.5)
Exhaust after Turbo	710(377)	16.60(9.23)	709(376)	23.6(13.1)
Water Jacket Inlet	159(70.5)	0.60(0.34)	159(70.5)	0.67(0.37)
Water Jacket Outlet	170(76.8)	0.45(0.25)	169(76.3)	0.86(0.48)
Oil Sump	223(106)	1.57(0.87)	213(101)	2.91(1.62)
Fuel at Filter	92.7(33.7)	4.19(2.33)	88.3(31.3)	1.32(0.73)
Inlet Air	91.2(32.9)	3.44(1.91)	90.3(32.4)	3.17(1.76)
Airbox	255.7(124)	3.42(1.90)	210(99)	3.50(1.95)
Pressures				
Exhaust before Turbo, psi(kPa)	10.81(74.5)	0.09(0.64)	6.98(48.1)	0.09(0.64)
Exhaust after Turbo, in. Hg(kPa)	2.62(8.84)	0.04(0.15)	1.55(5.23)	0.03(0.09)
Compressor Discharge, psi(kPa)	11.18(77.1)	0.06(0.39)	7.99(55.1)	0.06(0.39)
Blower Discharge, psi(kPa)	16.65(115.0)	0.34(2.33)	9.98(68.8)	0.09(0.63)
Oil Gallery, psi (kPa)	49.69(343)	0.15(1.01)	42.10(290)	0.28(1.90)
Intake Vacuum, in. H_2O(kPa)	6.60(1.64)	0.09(0.02)	3.80(0.95)	0.05(0.01)
Ambient Conditions				
Dry Bulb Temperature, °F(°C)	77.58(25.3)	4.08(2.27)	77.4(25.2)	3.44(1.91)
Wet Bulb Temperature, °F(°C)	75.76(24.3)	5.49(3.05)	75.3(24.0)	4.61(2.56)
Barometric Pressure, in. Hg(kPa) (Both modes of operation)	29.04(98.06)	0.07(0.02)		

*68% of the values for a given variable occur within ±1 standard deviation of the mean; 95% occur within ±2 standard deviations.

6V-53T
TEST 35
LUBRICANT ANALYSIS
Lubricant: AL-12186-L

	ASTM Test Method	Test Time, Hours 0	20
Kinematic viscosity at 40°C (104°F) cSt	D 445	33.89	--
Kinematic viscosity at 100°C (212°F) cSt	D 445	5.69	5.83
Total Acid Number mg KOH/g	D 664	1.57	--
Total Base Number mg KOH/g	D 664	3.61	--
Pentane B Insclubles wt%	D 893	0.00	--
Toluene B Insolubles wt%	D 893	0.00	--
Flash Point, °C	D 92	221	--

TOTAL CONSUMPTION AND WEAR METALS BY XRF

Test Time, Hours	Total Oil Consumed, lb(kg)	Wear Metals, ppm Fe	Cu
0		<10	<10
20	9.74 (4.42)	320	11

Average oil consumption rate: 0.49 lb/hr (0.22 kg/hr)

6V-53T
TEST 35
Lubricant: AL-12186-L

WEAR MEASUREMENTS*

Cylinder Liner Bore Diameter Change

	Cylinder Number 1L		2L		3L	
	T-AT**	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0031 (0.079)	-0.0001 (-0.003)	+0.0012 (0.030)	-0.0002 (-0.005)	+0.0033 (0.084)	+0.0029 (0.074)
Middle	+0.0013 (0.033)	+0.0007 (0.018)	+0.0005 (0.013)	0.0000	+0.0017 (0.043)	+0.0010 (0.025)
Bottom	+0.0003 (0.008)	+0.0004 (0.010)	+0.0002 (0.005)	+0.0002 (0.005)	+0.0001 (0.003)	+0.0002 (0.005)

	Cylinder Number 1R		2R		3R	
	T-AT*	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0008(0.020)	-0.0001(-0.003)	+0.0023(0.058)	+0.0010(0.025)	+0.0014(0.036)	-0.0004(-0.010)
Middle	+0.0003(0.008)	+0.0002(0.005)	+0.0018(0.046)	+0.0012(0.030)	+0.0006(0.015)	-0.0001(-0.003)
Bottom	+0.0001(0.003)	+0.0003(0.008)	0.0000	+0.0002(0.005)	+0.0002(0.005)	+0.0002(0.005)

Average Change

	T-AT	F-B
Top	+0.0020 (0.051)	+0.0005 (0.013)
Middle	+0.0010 (0.025)	+0.0005 (0.013)
Bottom	+0.0002 (0.005)	+0.0003 (0.008)

Overall average change: +0.0008 (0.020)

Piston Ring End Gap Change

Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1	+0.009(0.23)	+0.003(0.08)	+0.008(0.20)	+0.004(0.10)	+0.039(0.99)	+0.004(0.10)	+0.011(0.28)
2	+0.004(0.10)	+0.003(0.08)	+0.003(0.08)	+0.002(0.05)	+0.007(0.18)	+0.003(0.08)	+0.004(0.10)
3	+0.001(0.03)	+0.003(0.08)	+0.002(0.05)	+0.002(0.05)	+0.004(0.10)	+0.001(0.03)	+0.002(0.05)
4	+0.001(0.03)	+0.003(0.08)	+0.002(0.05)	+0.001(0.03)	+0.005(0.13)	0.000	+0.002(0.05)
5	+0.041(1.04)	+0.009(0.23)	+0.145(3.68)	+0.010(0.25)	+0.130(3.30)	+0.008(0.20)	+0.057(1.45)
6	+0.018(0.46)	+0.008(0.20)	+0.083(2.10)	+0.006(0.15)	+0.016(0.41)	+0.007(0.18)	+0.023(0.58)
7	+0.019(0.48)	+0.009(0.23)	+0.084(2.13)	+0.008(0.20)	+0.017(0.43)	+0.007(0.18)	+0.024(0.61)

Overall average change: +0.018(0.46)

*All dimensions are given in inches (mm).
**T-AT = Thrust-Antithrust Direction; F-B = Front-Back Direction.

6V-53T
TEST 35
Lubricant: AL-12186-L
POST TEST ENGINE CONDITION AND DEPOSITS

	1L	2L	3L	1R	2R	3R	Average A.
Cylinder Liner							
Intake Port Plugging, % restriction	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Liner Scuffing, % Area							
Thrust	100	12	100	1	100	16	54.83
Anti-Thrust	86	0	83	12	100	1	47.00
% Total Area Scuffed	93	6	91.5	6.5	100	8.5	50.92
						Overall:	50.92
% Area Bore Polished							
Thrust	0	2	0	2	0	2	1.00
Anti-Thrust	0	1	0	2	0	1	0.67
% Avg. Area Bore Polished	0	1.5	0	2	0	1.5	0.83
						Overall:	0.83
B. Pistons							
Ring Face Distress, (demerits)							
No. 1	66.25	34.00	28.75	21.00	72.50	32.50	42.50
No. 2	58.25	33.00	32.50	0.25	48.75	12.50	30.88
No. 3	55.50	40.00	28.75	0.00	51.75	13.50	31.58
						Overall:	34.99
Piston Skirt Rating							
Thrust	95%SC*	15%SC	95%SC	5%SC	25%PM/ 80%SC	5%SC	
Anti-Thrust	35%SC	5%SC	80%SC	5%SC	65%SC	S	
Piston WTD Rating**	151.63	126.38	147.5	131.00	179.00	148.63	147.36
Ring Sticking							
No. 1	F	F	F	F	CO***	F	
No. 2	F	F	F	F	F	F	
No. 3	F	F	F	F	F	F	
No. 4	F	F	F	F	F	F	
C. Exhaust Valves							
Deposits							
Head	← 1/4 AHC+ →						
Face	← 1/4 AHC →						
Tulip	← 1/4 AHC →						
Stem	← 1/4 AHC to #9 Lacquer++ →						
Surface Condition							
Freeness in Guide	F	F	F	F	F	F	
Head	← Normal →						
Face	← Normal →						
Seat	← Normal →						
Stem	← Normal →						
Tip	← Normal →						
D. Other Ratings							
Upper Oil Control Ring Expansive Force, lbs.	19.6	20.2	19.8	19.8	19.2	19.0	19.6
Main Bearings	# 2 main bearing has scratches and metal flaking						
Rod Journals	Scratched						
Tappets, Cams and Rocker Arm Condition	Cam lobes show light to medium wear with scratches						

*L = Light, S = Scratches, PM = Plating Melted, N = Normal, SC = Scuffing, B = Burn
**CRC Weighted Total Deposits (0 = least, 900 = most)
***HS = Hotstuck, CS = Cold Stuck, P = Pinched, F = Free, N = Normal, C = Chipped, CO = Collapsed
+HC = Hard Carbon; the number-letter, prefix indicates carbon depth with 1/4 A = least to J = most
++ = The higher the number, the darker the lacquer (0 = lightest, 9 = darkest)

6V53T(#35)
1-L

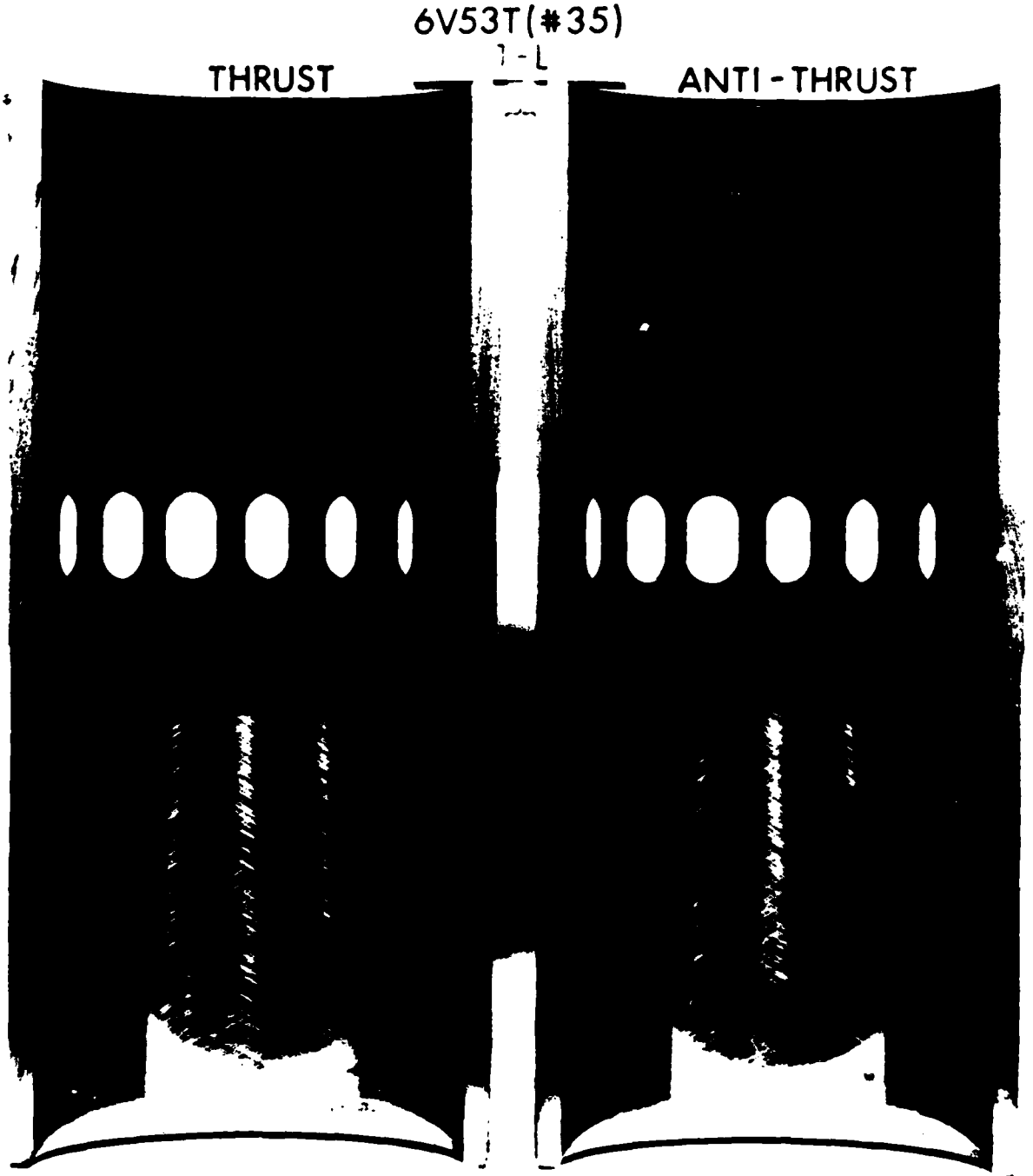
6V53T(#35)
1-R

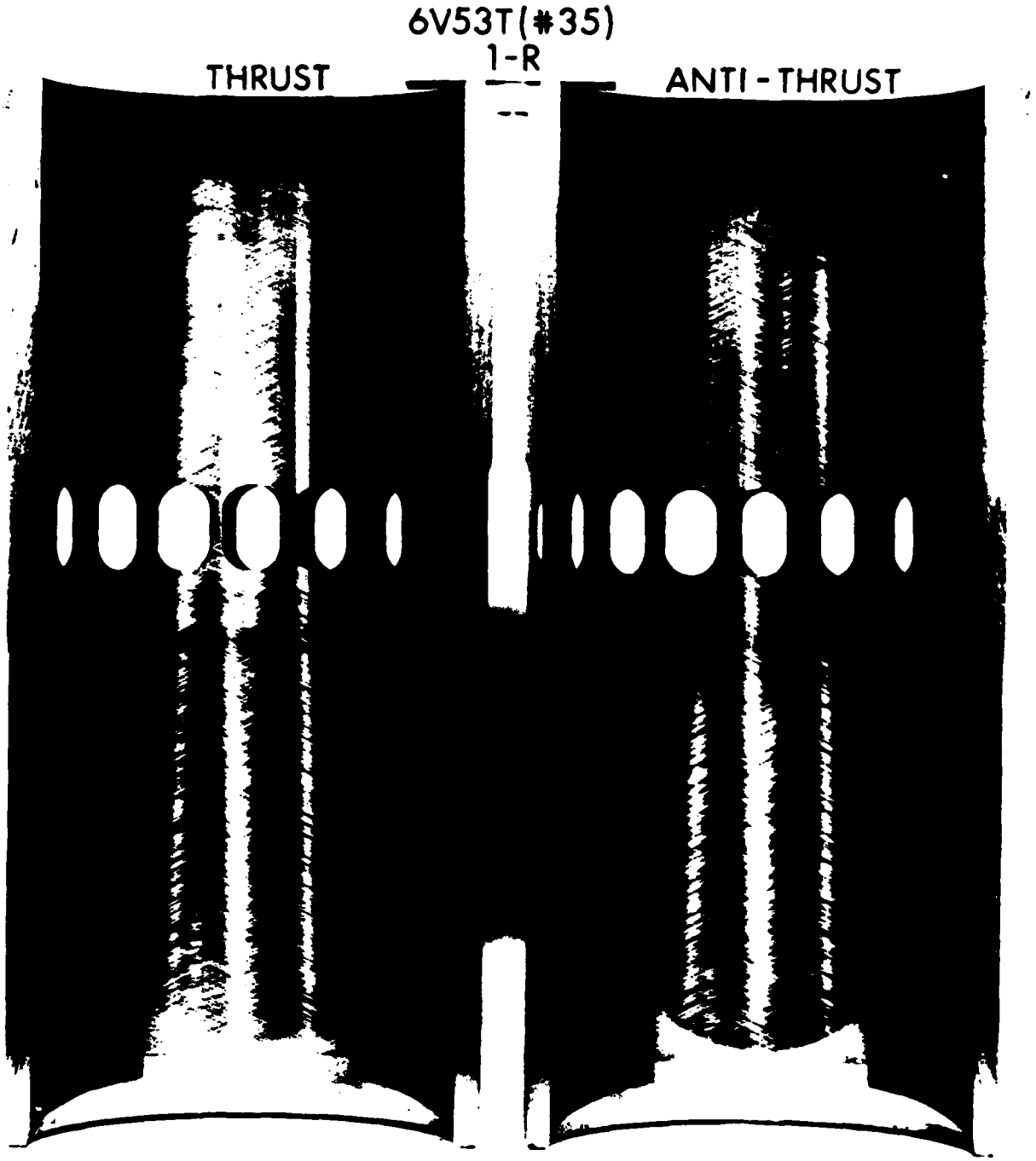
6V53T(#35)
1-L-T

6V53T(#35)
1-L-AT

6V53T(#35)
1-R-T

6V53T(#35)
1-R-AT


6V53T(#35)
1-L
THRUST
ANTI-THRUST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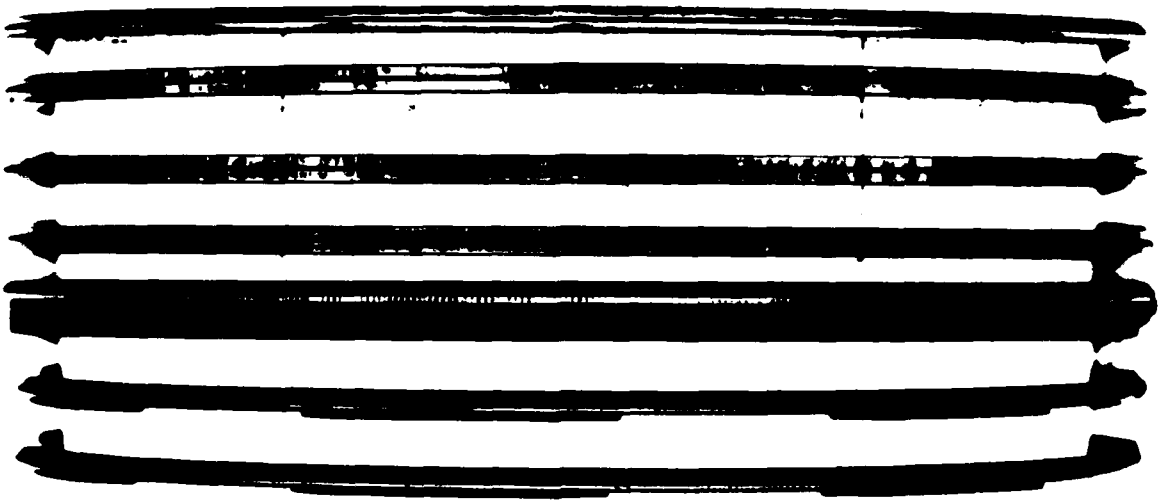
1-R
THRUST
ANTI - THRUST

6V53T(#35)
2-L



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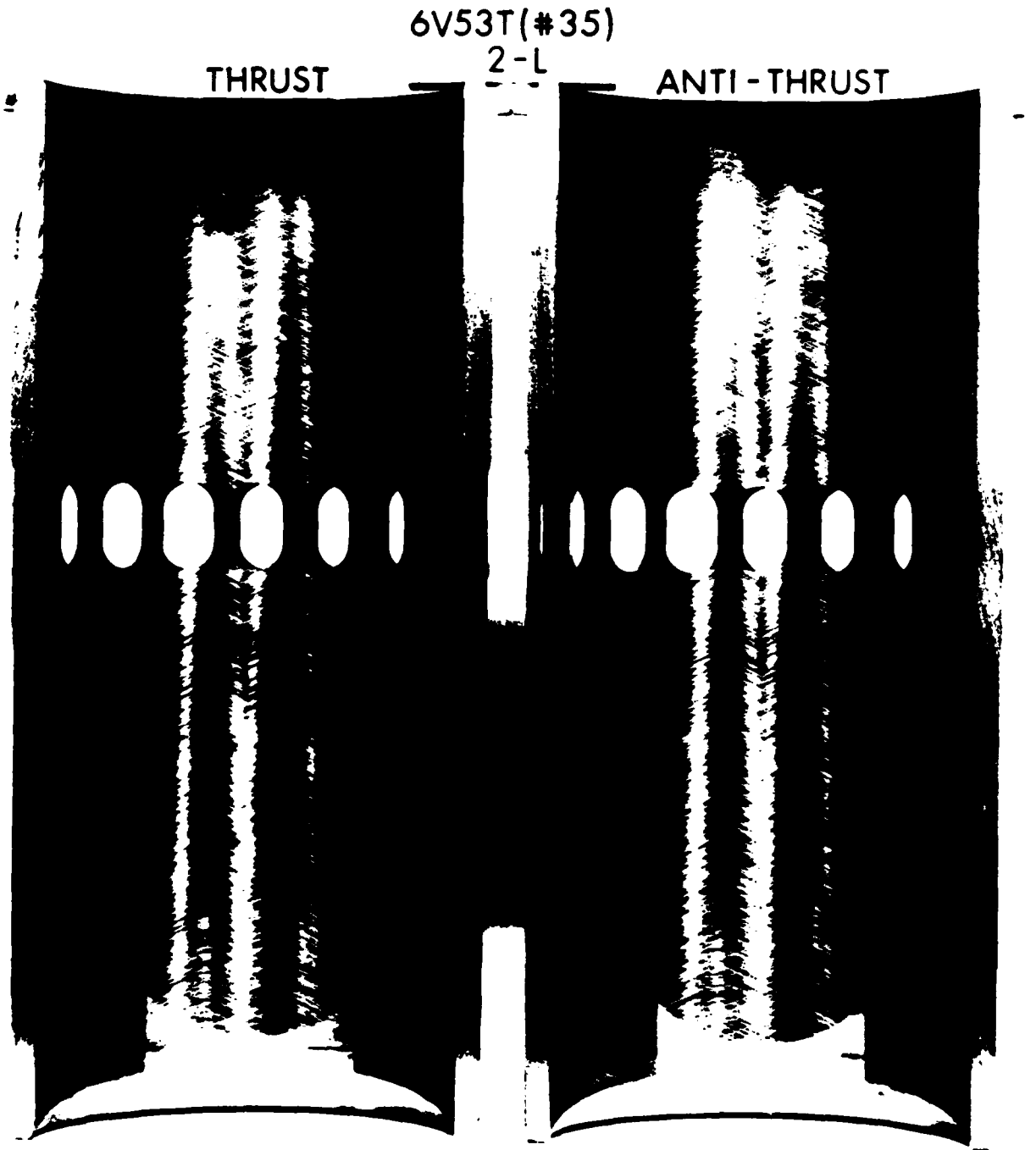
2-R

6V53T(#35)
2-L-T

6V53T(#35)
2-L-AT

6V53T(#35)
2-R-T

6V53T(#35)
2-R-AT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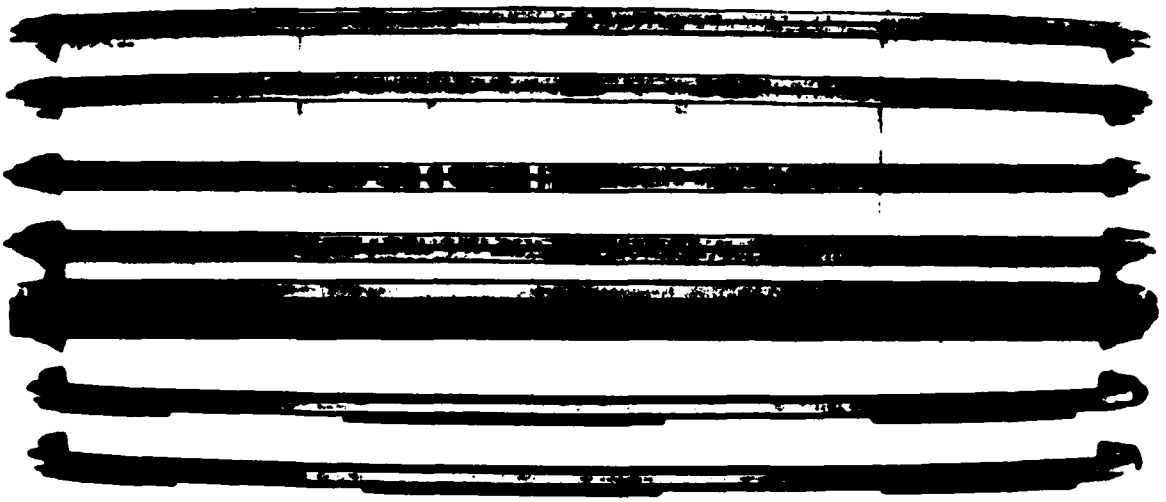
2-L
THRUST
ANTI-THRUST

6V53T(#35)
2-R

THRUST

ANTI-THRUST

6V53T(#35)
3-L



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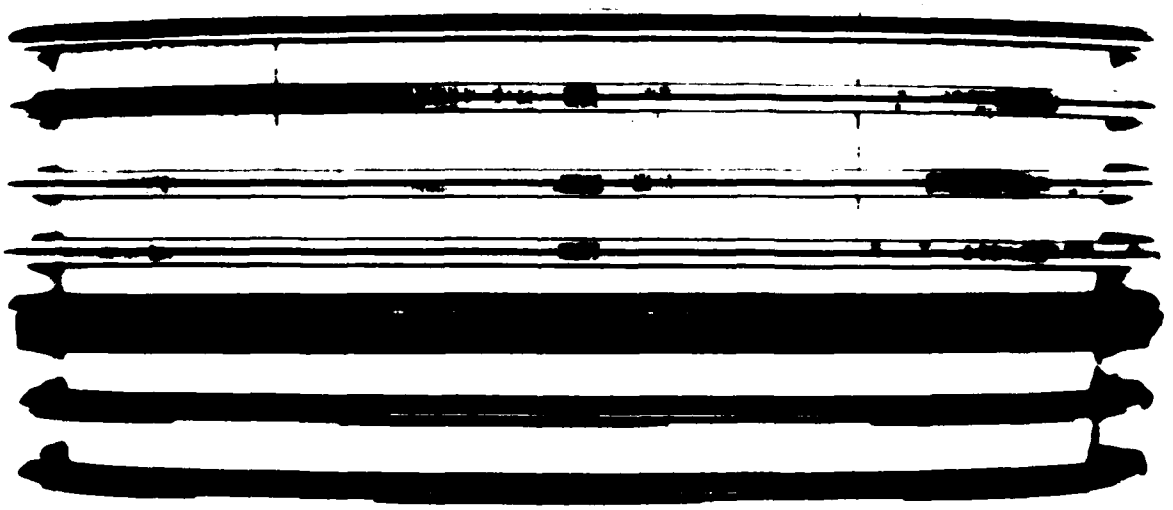

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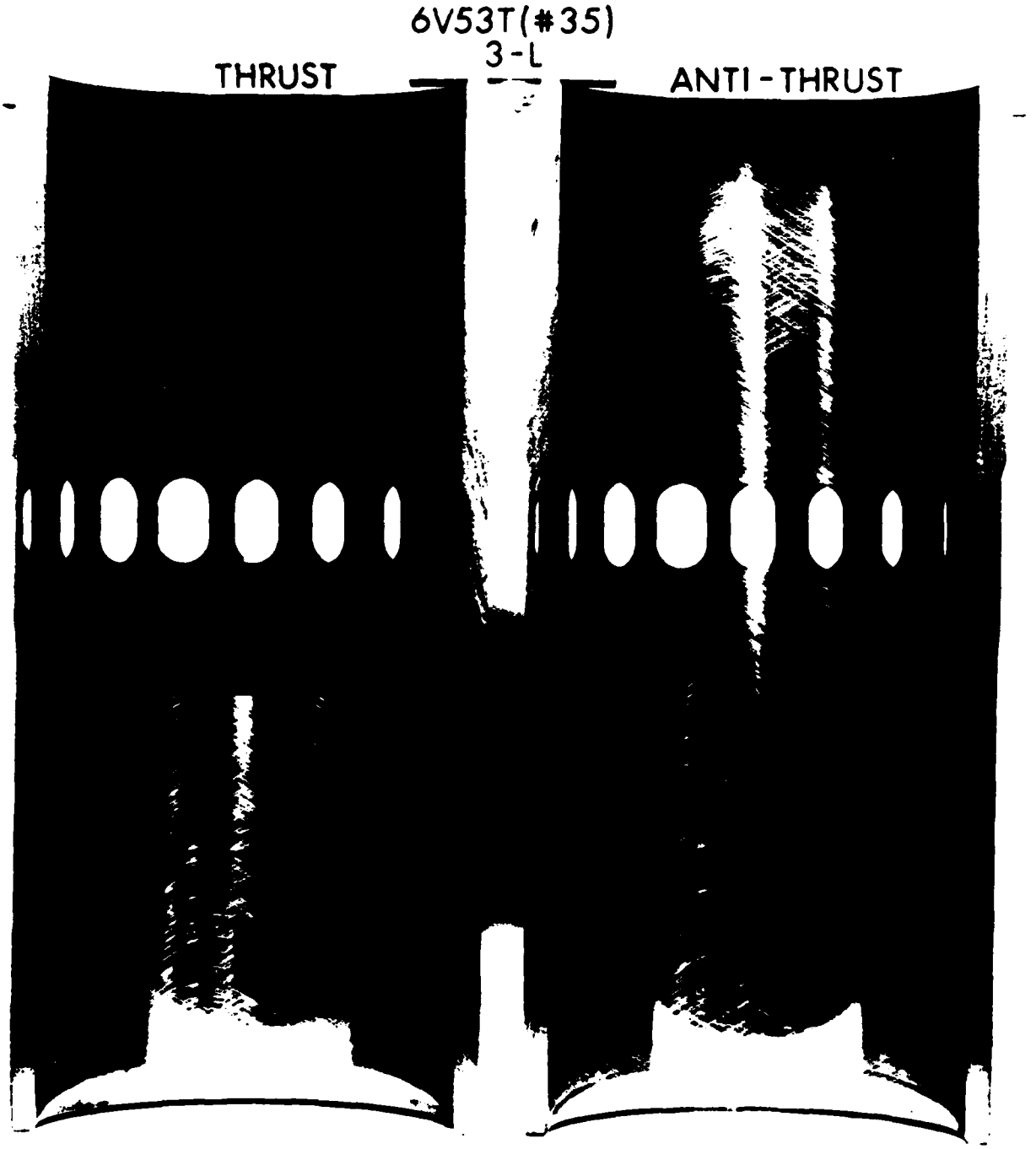
3-L-T

6V53T(#35)
3-L-AT

6V53T(#35)
3-R-T

6V53T(#35)
3-R-AT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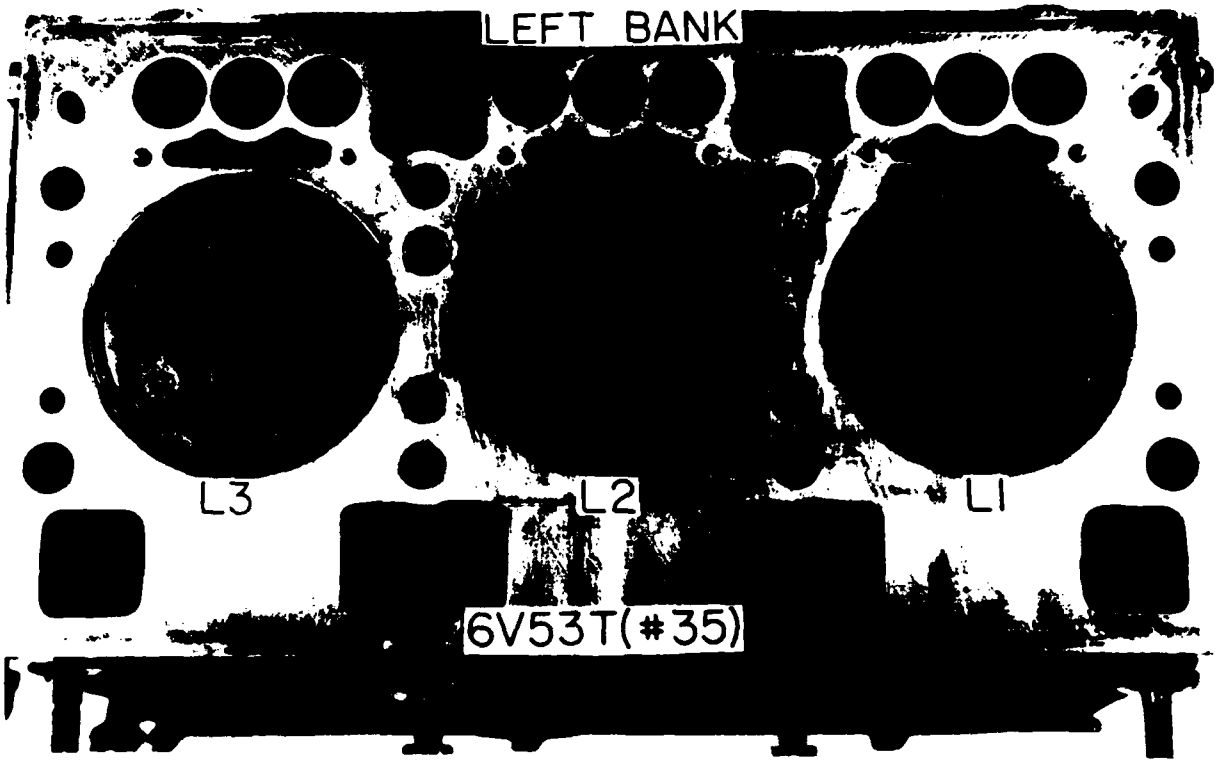
3-L
THRUST
ANTI-THRUST


6V53T(#35)
3-R
THRUST
ANTI-THRUST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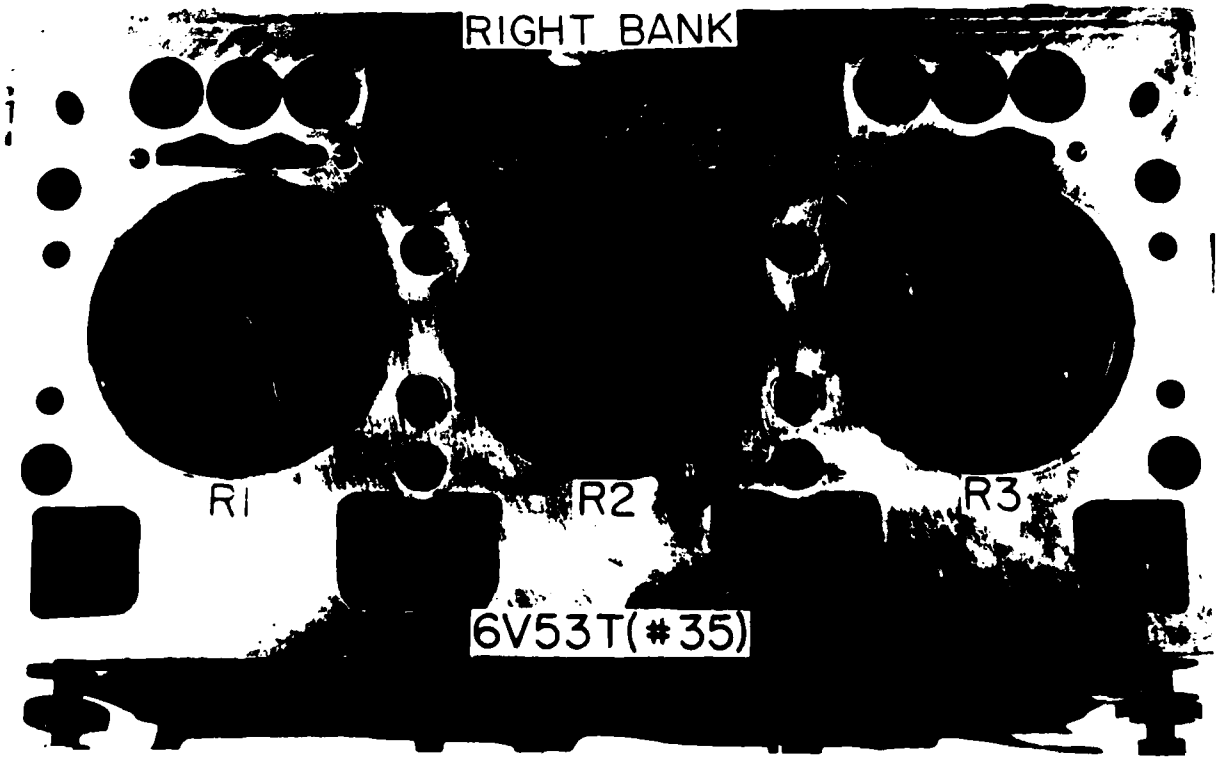
L2
L1
6V53T(#35)


RIGHT BANK
R1
R2
R3
6V53T(#35)

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